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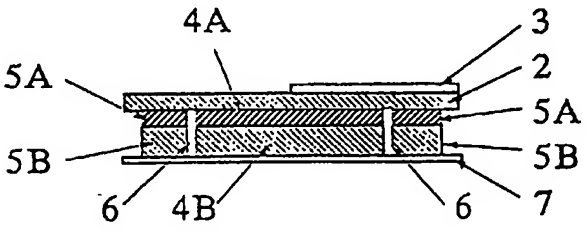
(54) DEVICE FOR IONTOPHORESIS

(57) This invention relates to an iontophoretic device for the electrical percutaneous administration of a drug. As its features, a backing is provided with a power source, and a donor and a receptor are arranged on the same side of the backing with an insulating space region interposed therebetween, whereby the device has an integral structure. This iontophoretic device permits safe and efficient percutaneous absorption of a drug without increasing a current value and also features extremely good handling ease.

Fig. 2



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Description

Technical Field

[0001] This invention relates to a device for the electrical percutaneous administration of a drug, and more specifically to an iontophoretic device with a donor and a receptor arranged in an integral structure for the electrical percutaneous administration of a drug.

Background Art

[0002] As methods for the administration of drugs, there are oral administration, transmucosal administration, transdermal administration, and the like. Transdermal administration features advantages such as 1) exhibition of pharmacological effects by a small amount of a drug, 2) possibility of topical administration, 3) avoidance of side effects on various organs, and 4) concerning peptide or protein preparations, avoidance of *in vivo* degradation. On the other hand, transdermal administration is accompanied by problems such as a) low absorption of a drug having a high molecular weight, b) low absorption of a hydrophilic drug, and c) difficult controllability of dose.

[0003] With a view to overcoming these problems, investigations have been made *inter alia* on methods making use of additives such as chemical enhancers, phonophoresis involving exposure to electromagnetic radiation such as ultrasonic waves, and iontophoresis featuring transport of a drug by an electric current.

[0004] Of these, the methods which make use of additives such as chemical enhancers have been studied with respect to aprotic polar solvents (Stoughton R.B., Fritsh W., Arch. Dermatol., No. 90, P. 512, 1964), surfactants (Woodford R., Barry B.W., J. Toxicol.-Cut & Ocular Toxicol., No. 5, P. 167, 1986), fatty acids and their derivatives (Cooper E.R., J. Pharm. Sci., No. 73, P. 1153, 1984), esters (Catz P., Friend D.R., J. Control Rel., No. 12, P. 171, 1990), etc. Although they are effective for hydrophobic drugs having relatively low molecular weights, they are accompanied by a problem such that stratum corneum may be separated or dissolved to cause a damage on skin, modification or degradation may be promoted for a peptide or protein preparation or dose control may be difficult. The use of phonophoresis is effective for the enhancement of percutaneous absorption (Bommanman D., Okuyama H., Stauffer P., Guy R., Pharm. Res., No. 9, P. 559, 1992), but this method is accompanied by a problem that, when exposed to electromagnetic radiation concurrently with administration, modification or degradation may be promoted or control of dose may be difficult. On the other hand, use of iontophoresis makes it possible to control the dose by suitably adjusting an electric current, although this method is accompanied by a problem that application of an excess current may promote a skin damage, such as burn, or degradation of a drug.

[0005] Concerning iontophoresis, percutaneous absorption enhancing effects of anionic drugs (Miller L.L., Smith G.A., Int. J. Pharm., No. 49, P. 15, 1989), cationic drugs (Siddiqui O., Roberts M.S., Polack A.E., J. Pharm. Pharmacol., No. 37, P. 732, 1985) and peptide or protein preparations (Banga A.K., Chien Y.W., Pharm. Res., No. 7, P. 10, S185, 1990) as well as percutaneous noninvasive extraction of nonionic substances based on the theorem of electroosmosis have been reported. Clinically, treatments of post herpetic neuralgia by using lidocaine, epinephrine, methylprednisolone or indomethacin (Ozawa Akira, NIHON IJI SHINPO, No. 3648, P. 25, 1994) have also been conducted.

[0006] In these treatments, however, a square or circular absorbent cotton impregnated with a drug solution and applied with an aluminum foil as an electrode is provided for use on a donor side, an absorbent cotton of a similar construction and impregnated with an aqueous solution of an electrolyte such as sodium nitrate is provided for use on a receptor side, they are brought into close contact with skin by surgical tapes or the like with an appropriate interval left therebetween, and a constant-current device called "Phoresor" is used. This method is accompanied by problems such that no effective absorption may be achieved due to low efficiency of electric quantity and insufficient contact between the electrodes and the absorbent cottons and between the absorbent cottons and the skin and the need for complex procedures and the large device makes it impossible to apply this method for the administration of a drug at home.

[0007] Although use of an increased current value is an only means for increasing an absorption rate or for achieving absorption of a low-absorption drug, such an increased current value has led to the problem of occurrence of burn as mentioned above. Hence, with a view to enhancing the absorption of a drug without increasing the current value, improvements have been made, for example, on i) voltage, ii) current application method, iii) electrode construction, iv) electrode pads, and the like as will be described next.

i) As a power source, a small battery has been disclosed, which is equipped with a relatively short service life and has a high internal impedance as producing no overcurrent even when a significant drop takes place in skin resistance due to sweating or the like (JP Kokai No. 3-254759).

ii) As a power application method, application of a pulsed current was studied to achieve depolarization of skin (Gupta, S.K., et al., J. Control Rel. No. 31, P. 229, 1994). This method is however accompanied by problems that it is effective only for certain specific drugs and that, as it requires a circuit and another power source for the production of a pulsed current, its apparatus is complex, has difficulty in operation and is costly.

iii) Disclosed as electrode constructions include plural donors and receptors arranged on the same flat surface with insulators interposed therebetween (JP Kokai No. 3-133464); plural donors and receptors concentrically arranged to control release of plural effective ingredients in accordance with a program (JP Kokai No. 4-208166); and a polygonal donor included within a receptor, said donor and said receptor being arranged on the same flat surface with an insulating part, which has a skin-contacting portion, interposed therebetween to avoid leakage of a current at the insulating part (JP Kokai No. 3-133464). Incidentally, although the plural receptors are used in JP Kokai No. 3-133464 to improve absorption, the absorption is not improved practically by increasing the number of receptors (see Test 9 to be described subsequently herein). Further, JP Kokai No. 4-208166, without any substantiation, states that a concentric arrangement of electrodes minimizes an electric current required for the release of a drug. However, even among concentric electrode constructions, the absorption varies depending on factors such as the width of the insulating part and the area ratio of the donors to the receptors (see Tests 10 and 11 to be described subsequently herein). In addition, it is an essential requirement in JP Kokai No. 8-185016 to have the skin-contacting portion in the insulating part. This skin-contacting portion has a stronger significance as an adhesion-assisting means for a drug-containing matrix having no adhesion to the skin, such as an agar gel, rather than inhibition of a deterioration in absorption as a result of leakage of a current, which flows between the donor and the receptor, on the skin surface.

iv) Disclosed as electrode pads include those having excellent peel strength to the skin even when water is contained therein and, by themselves, remaining free of changes in form and the like when a current is passed therethrough (JP Kokai No. 8-325545).

[0008] It is however the current situation that no satisfactory iontophoretic device is still unavailable despite these improvements.

[0009] An object of the present invention is therefore to provide an iontophoretic device which permits safe and efficient percutaneous absorption of a drug without increasing a current value and also has excellent handling ease.

Disclosure of the Invention

[0010] The present invention have hence proceeded with a variety of research to achieve the above-described object, resulting in the completion of an iontophoretic device according to the present invention which is composed of a integral structure of a donor and a receptor.

[0011] Namely, the present invention has achieved the above-described object by an iontophoretic device for the electrical percutaneous administration of a drug, comprising: a backing provided with a power source, and a donor and a receptor arranged on the same one side of the backing with an insulating space region interposed therebetween, whereby the device has an integral structure.

Brief Description of the Drawings

[0012]

FIG. 1 is a schematic plan view of an iontophoretic device according to the present invention. FIG. 2 is a schematic cross-sectional view of the iontophoretic device according to the present invention. FIG. 3 is a schematic bottom view of the iontophoretic device according to the present invention from which a liner has been peeled off. FIG. 4 is a schematic plan view showing another embodiment of the iontophoretic device according to the present invention. FIG. 5 is a flow chart illustrating production steps for the iontophoretic device according to the present invention. FIG. 6 is a schematic diagram showing the principle of iontophoresis by the iontophoretic device according to the present invention. FIG. 7 is a schematic illustration showing an example of a paired arrangement of a donor and a receptor in the same plane, with the width of an insulating space region varied as will be described in Test 1. FIG. 8 is a graph showing, as a result of Test 1, a relationship between the variations in the width of the insulating space region and AUC. FIG. 9 is a schematic illustration showing an example of a paired and surrounded/surrounding arrangement of a donor and a receptor in Test 2. FIG. 10 is a graph showing, as a result of Test 2, a relationship between the donor-receptor arrangement and AUC. FIG. 11 is a schematic illustration showing examples of a surrounded/surrounding arrangement of a donor and a receptor and examples of the shapes of the donor and receptor. FIG. 12 is a graph showing a relationship between the shapes of the donor and the receptor and AUC as ascertained as a result of Test 3. FIG. 13 is a schematic illustration depicting examples of a surrounded/surrounding arrangement of a donor and a receptor in Test 4. FIG. 14 is a graph showing, as a result of Test 4, a relationship between the surrounded/surrounding arrangement of the donor and the receptor and AUC. FIG. 15 is a schematic illustration showing an example of a paired and surrounded/surrounding arrangement of a donor and a receptor in Test 5. FIG. 16 is a graph showing, as a result of Test 5, a relationship between the donor-receptor arrangement and AUC. FIG. 17 is a schematic illustration

showing examples of a surrounded/surrounding arrangement of a donor and a receptor and examples of the shapes of the donor and receptor. FIG. 18 is a graph showing, as a result of Test 6, a relationship between the shapes of the donor and the receptor and AUC. FIG. 19 is a schematic illustration showing examples of a surrounded/surrounding arrangement of a donor and a receptor and examples of the shapes of the donor and receptor. FIG. 20 is a graph showing, as a result of Test 7, a relationship between the kind (space/adhesive tape) of an insulating region between the donor and the receptor and AUC. FIG. 21 is a front illustration of a "PHEO METER" employed in Test 8. FIG. 22 is a graph showing peel strength of an agar pad disclosed in JP Kokai No. 7-185016 and an adhesive pad according to the present invention, which has been obtained as a result of Test 8. FIG. 23 is a schematic illustration showing examples of the number of receptor(s) and a surrounded/surrounding relationship of the receptor(s) with a donor as well as examples of the receptor(s) and donor. FIG. 24 is a graph showing, as a result of Test 9, a relationship between the number of the receptor(s) and AUC. FIG. 25 is a schematic illustration depicting examples of a surrounded/surrounding arrangement of a donor and a receptor in the same plane, with the width of an insulating space region varied as will be described in Test 10. FIG. 26 is a graph showing, as a result of Test 10, a relationship between the variations in the insulating with and AUC. FIG. 27 is a schematic illustration showing examples of a surrounded/surrounding arrangement of a donor and a receptor at different receptor/donor area ratios and examples of the shapes of the donor and receptor, which will be described in Test 11. FIG. 28 is a graph depicting, as a result of Test 11, a relationship between the receptor/donor area ratio and AUC. FIG. 29 is a schematic illustration showing examples of a surrounded/surrounding arrangement of a donor and a receptor at different receptor/donor area ratios and exampies of the shapes of the donor and receptor, which will be described in Test 12. FIG. 30 is a graph depicting, as a result of Test 12, a relationship between the receptor/donor area ratio and AUC. FIG. 31 is a schematic illustration showing examples of a surrounded/surrounding arrangement of a donor and a receptor at different receptor/donor area ratios and examples of the shapes of the donor and receptor, which will be described in Test 13. FIG. 32 is a graph showing, as a result of Test 13, a relationship between the receptor/donor area ratio and an amount of lidocaine permeated in the skin. FIG. 33 is a schematic illustration showing examples of the shape of an outer peripheral portion, one being a circle and the other a square, which will be described in Test 14. FIG. 34 is a graph showing, as a result of Test 14, a comparison in the amount of lidocaine permeated in the skin between the circular outer peripheral portion and the square outer peripheral portion. FIG. 35 is a schematic illustration showing examples of the shape of an outer peripheral portion, one being a square and the other a round-cornered square, which will be described in Test 15. FIG. 36 is a graph showing, as a result of Test 15, a comparison in the amount of lidocaine permeated in the skin between the square outer peripheral portion and the round-cornered square outer peripheral portion.

[0013] The following is an explanatory list of symbols in the drawings.

1: power source, 1a: switch, 1b: current application stop control circuit, 2: backing, 3: power source mount, 4: donor, 4A: donor electrode plate, 4B: donor adhesive pad, 5: receptor, 5A: receptor electrode plate, 5B: receptor adhesive pad, 6: insulating space region, 7: liner.

Best Mode for Carrying Out the Invention

[0014] The embodiment of the present invention will hereinafter be described based on FIGS. 1 through 4.

[0015] Numeral 1 indicates a power source, which is to be arranged on an upper side of a backing 2. Although this power source 1 may be fixedly assembled beforehand on the upper side of the backing 2, an arrangement of a battery mount 3 on the upper side of the backing 2 to permit detachable mounting of the power source 1 there is more preferred from the standpoint of safety because the power source 1 can be mounted only when the device is used. No particular limitation is imposed on the specific mounting position of the power source 1 insofar as it is on the upper side of the backing 2. The mounting position can therefore be at a central part close to a right side as shown in FIG. 1 or at a lower right corner part as depicted in FIG. 4. Further, it is preferred to additionally provide the backing 2 with an on/off switch 1a for the power source 1 or a circuit 1b for stopping current application in a predetermined time.

[0016] Illustrative of the power source 1 for use in the present invention can be a button battery, a cylindrical battery, and a film battery. Use of a film battery is particularly preferred, as it is thin, flexible and free of harmful substances such as mercury, cadmium and lead.

[0017] Preferred examples of the backing 2 for use in the present invention can include sheets of plastics such as polyethylene, polypropylene, ethylene-vinyl acetate copolymer, vinylon, polyesters, polyurethanes and nylon; non-woven fabrics of rayon and polyesters; and woven fabrics of polyesters, acrylic resins, silk and cotton. Among non-woven fabrics, a spun lace is partic-

ularly advantageous for its high flexibility.

[0018] Designated at numerals 4 and 5 are a donor and a receptor, respectively. They are arranged on the same lower side of the backing 2 with an insulating space region 6 interposed therebetween, and are in the form of an integral structure as a whole. Setting of the width of the insulating space region 6, that is, the distance from the donor 4 to the receptor 5 at 0.5 to 12 mm, especially at 1 to 6 mm brings about especially good results in the percutaneous absorption of a drug. Incidentally, if the width of the insulating space region 6 is narrower than the above range, a current passes primarily through a high-resistance stratum corneum in a skin surface, thereby resulting in a reduction in the percutaneous absorption of the drug. On the other hand, a width greater than the above range leads to a reduced current intensity and hence to lowered percutaneous absorption of the drug.

[0019] Although no limitation is imposed on the positional relationship between the donor 4 and the receptor 5, it is especially preferred for the attainment of excellent percutaneous absorption efficiency of a drug to arrange the donor 4 and receptor 5 in a surrounding/surrounded or surrounded/surrounding relationship with the insulating space region 6 interposed therebetween as illustrated in FIG. 3.

[0020] As the donor 4 for use in the present invention, one having an adhesive pad 4B, which contains a drug solution or a drug and an electrolyte solution, on a lower side of an electrode plate 4A is advantageous from the standpoint of convenience for use in a state attached to the skin. As the receptor 5, on the other hand, one having an adhesive pad 5B, which contains a drug and an electrolyte solution or an electrolyte solution, on a lower side of an electrode plate 5A is advantageous from the same standpoint.

[0021] Preferred examples of the electrode plates 4A,5A include those made of one or two metals selected from aluminum (including aluminum oxide), stainless steel, gold, silver, silver chloride, platinum and platinum black.

[0022] The drug-containing solution is composed of the drug and a solvent. No particular limitation is imposed on the drug insofar as it can be absorbed percutaneously. Illustrative are protein or peptide preparations; antipyretic, antiphlogistic and analgesic agents; steroidal antiphlogistics; vasodilators; antihypertensive and antiarrhythmic agents; antihypertensive agents; antitussive expectorants; antitumor agents; local anesthetics; hormonal agents; antiallergic agents; antihistamic agents; anticoagulants; antispasmodics; celebral circulation and metabolism improvers; antidepressant anxiolytics; vitamin D preparations; hypoglycemics; antiulcerative agents; hypnotics; antibiotics; antifungal agents; sedatives; bronchodilators; virucides; dysuria treating agents; and parasympathomimetics.

[0023] Illustrative of the protein or peptide preparations are insulin, calcitonin, elcatonin, vasopressin, arginine-vasopressin, batroxobin, gonadorelin acetate, octreotide acetate, desmopressin acetate, nafarelin acetate, buserelin acetate, leuprorelin acetate, salmon calcitonin, somatropin, hyaluronidase, prolethilerin, and angiotensin II.

[0024] Illustrative of the antipyretic, antiphlogistic and analgesic agents are indomethacin, salicylic acid, sodium salicylate, aspirin, acetaminophen, diclofenac sodium, ibuprofen, sulindac, naproxen, ketoprofen, flufenamic acid, ibufenac, fenbufen, alclofenac, phenylbutazone, mefenamic acid, bendazac, piroxicam, flurbiprofen, pentazocine, buprenorphine hydrochloride, and butorphanol tartrate.

[0025] Illustrative of the steroidal antiphlogistics are hydrocortisone, prednisolone, fluocinolone acetonide, fludroxycortide, methylprednisolone, hydrocortisone acetate, triamcinolone acetonide, dexamethazone, betamethasone acetate, diflucortolone valerate, clobetasol propionate, and fluocinonide.

[0026] Illustrative of the vasodilators are diltiazem, verapamil, pentaerythritol tetranitrate, dipyridamole, isosorbide nitrate, nifedipine, niconinic acid, and norepinephrine.

[0027] Illustrative of the antihypertensive and antiarrhythmic agents are propranolol, atenolol, pindolol, quinidine sulfate, azimaline, alprenolol hydrochloride, metoprolol tartrate, nadolol, timolol maleate, disopyramids, diltiazem hydrochloride, and mexiletine hydrochloride.

[0028] Illustrative of the antihypertensive agents are clonidine hydrochloride, captopril, prazosin hydrochloride, penbutolol sulfate, guanabenz acetate, guanfacine hydrochloride, bunazosin hydrochloride, enalapril maleate, arotinolol hydrochloride, binitrolol hydrochloride, and quanethidine sulfate.

[0029] Illustrative of the antitussive expectorants are procaterol hydrochloride, terbutaline sulfate, fenoterol hydrobrimide, tulobuterol hydrochloride, ambroxol hydrochloride, pirbuterol hydrochloride, mabuterol hydrochloride, clenbuterol hydrochloride, trimetoquinol hydrochloride, and formoterol fumarate.

[0030] Illustrative of the antitumor agents are vincristine sulfate and vinblastine sulfate.

[0031] Illustrative of the local anesthetics are benzocaine (hydrochloride), prilocaine (hydrochloride), lidocaine (hydrochloride), tetracaine (hydrochloride), bupivacaine (hydrochloride), and mepivacaine (hydrochloride).

[0032] Illustrative of the hormonal agents are steroidal hormones such as estrogen, estradiol, tetrasterone, progesterone, prostaglandin, dinoprost and ritodrine hydrochloride; adrenal hormones such as hydroxycortisone succinate sodium, methylpredonisolone succinate sodium, cortisone acetate, triamcinolone acetate, dexamethasone, hydrocortisone, predonisolone, methylpredonisolone, dexamethasone phosphate sodium hydrocortisone phosphate sodium and epinephrinel; and peptide hormones such as insulin.

[0033] Illustrative of the antiallergic agents are ketotifen fumarate, emedastine fumarate, azelastine hydrochloride, sodium cromoglycate, tranilast, cyclosporin, auranofin, tacrolimus hydrate, diphenhydramine hydrochloride, diphenylpyraline hydrochloride, promethazine hydrochloride, diphenylpyraline teoclate, chlorpheniramine maleate, and bucillamine.

[0034] Illustrative of the antihistaminic agents are cycloheptadine hydrochloride, diphenhydramine hydrochloride, fenbenzamine, mequitazine and chlorpheniramine maleate.

[0035] Illustrative of the anticoagulants are heparin, urokinase, and t-PA.

[0036] Illustrative of the antispasmodics are scopolamine, clofloperol, N-methylscopolamine methylsulfate, and papaverine hydrochloride.

[0037] Illustrative of the cerebral circulation and metabolism improvers are vinpocetine, flunarizine hydrochloride, nicardipine hydrochloride, brovincamine fumarate, dihydroergotoxine mesylate, ifenprodil tartrate, isoxsuprine hydrochloride, diltiazem hydrochloride, etidronate disodium, and dilazep hydrochloride.

[0038] Illustrative of the antidepressant anxiolytics are maprotiline hydrochloride, etizolam, diazepam, bromazepam, amitriptyline hydrochloride, mianserin hydrochloride, chlorpromazine, spiperone, and imipramine hydrochloride.

[0039] Illustrative of the vitamin D preparations are alfacalcidol and ergocalciferol.

[0040] Illustrative of the hypoglycemics are glibenclamide and glyclazide.

[0041] Illustrative of the antiulcerative agents are clebopride malate, famotidine, glycopyrronium bromide, and fluorouracil.

[0042] Illustrative of the hypnotics are phenobarbital and amobarbital.

[0043] Illustrative of the antibiotics are tetracycline, chloramphenicol, phenoxymethylpenicillin potassium, and erythromycin.

[0044] Illustrative of the antifungal agents are ciclopiroxolamine and amphotericin B.

[0045] Illustrative of the sedatives are scopolamine hydrobromide, morphine hydrochloride, and fentanyl citrate.

[0046] Illustrative of the bronchodilators are theophylline, formoterol fumarate, salbutamol sulfate, terbutaline sulfate, and ephedrine hydrochloride.

[0047] Illustrative of the virucides are vidarabine and idoxuridine.

[0048] Illustrative of the dysuria treating agents are oxybutynin hydrochloride, arginine-vasopressin, desmopressin acetate, and furosemide.

[0049] Illustrative of the parasympathomimetics is acetylcholine chloride.

[0050] The proportion of each drug may desirably range from 0.1 to 10 wt.%, although it differs depending on the amount clinically required as its ordinary single dose.

[0051] Examples of the solvent can include water; polyhydric alcohols such as ethylene glycol, diethylene glycol, triethylene glycol, ethylene glycol monoethyl ether, ethylene glycol monobutyl ether, diethylene glycol monomethyl ether, polyethylene glycol, propylene glycol, polypropylene glycol, glycerin, batyl alcohol, pentaerythritol, and sorbitol; and alcohols such as ethanol, isopropyl alcohol, lauryl alcohol, cetanol, stearyl alcohol, oleyl alcohol, and lanolin alcohol. They can be used either singly or in combination.

[0052] Among these solvents, mixed solvents of polyhydric alcohols, alcohols and water are preferred. Further, polyethylene glycol and propylene glycol are preferred as polyhydric alcohols, and ethanol and isopropyl alcohol are preferred as alcohols. The mixing ratio of these solvents varies depending on the solubility of a drug, but a mixing ratio of polyhydric alcohol:alcohol:water = 0.5-9:0-2:1 is preferred.

[0053] In addition, oils and fats, fatty acids, preservatives (antiseptics), stabilizers (antioxidants), surfactants, conductivity-imparting substances and chemical enhancers can be added as needed.

[0054] Examples of the oils and fats can include cotton seed oil, olive oil, cacao butter, and palm oil.

[0055] Examples of the fatty acids can include propionic acid, butyric acid, valeric acid, caproic acid, heptanoic acid, caprylic acid, nonanoic acid, decanoic acid, undecanoic acid, dodecanoic acid, lauric acid, myristic acid, palmitic acid, palmitoleic acid, stearic acid, oleic acid, linoleic acid, and linolenic acid.

[0056] Examples of the preservatives can include phenolic substances such as methyl paraoxybenzoate, phenol and cresol; neutral substances such as chlorobutanol and phenylethyl alcohol; invert soaps such as benzalkonium chloride and benzethonium chloride; and acidic substances such as benzoic acid, sorbic acid, dehydroacetic acid, and salicylic acid.

[0057] Examples of the stabilizers can include antioxidants such as vitamin E and butylhydroxyanisole; reducing agents such as ascorbic acid, sodium hydrogen-sulfite and sodium thiosulfate; and synergists such as citric acid (sodium citrate), tartaric acid (sodium tartrate), lecithin, and EDTA.

[0058] Examples of the surfactants can include anionic surfactants such as calcium stearate, magnesium stearate and sodium lauryl sulfate; cationic surfactants such as benzalkonium chloride, benzethonium chloride and cetylpyridinium chloride; and nonionic surfactants such as glyceryl monostearate, sucrose fatty acid ester, polyoxyethylene-hydrogenated castor oil, and polyoxyethylene sorbitan fatty acid ester.

[0059] Examples of the conductivity-imparting substances can include electrolytes such as sodium chloride, potassium chloride, sodium bromide, potassium bromide, calcium chloride, and calcium bromide.

[0060] Examples of the chemical enhancers can include nonionic surfactants such as glyceryl monostearate and sucrose fatty acid ester; water-soluble high

molecular compounds such as carboxylic acids; water-soluble chelating agents such as EDTA; aromatic carboxylic acid compounds such as salicylic acid and derivatives thereof; aliphatic carboxylic acid compounds such as capric acid and oleic acid; bile acid salts; propylene glycol; hydrogenated lanolin; isopropyl myristate; diethyl sebacate; urea; lactic acid; and Azone.

[0061] As an adhesive polymer for making up adhesive pads in the present invention, a water-soluble polymer or a water-soluble polymer having a crosslinked gel structure is preferred when a hydrophilic drug and a solution are used. Illustrative are polyglucosyloxyalkyl (meth)acrylates, polyhydroxyalkyl (meth)acrylates, polyacrylic acid, polyacrylate salts, polyurethanes, polyvinyl alcohol, polyvinylpyrrolidine, carboxymethylcellulose sodium, gelatin, starch, and agar. Use of a polyglycosyloxyalkyl (meth)acrylate or a polyhydroxyalkyl (meth)acrylate, a polyurethane or polyvinyl alcohol is particularly preferred.

[0062] When a hydrophobic drug and a solvent are used, a hydrophobic polymer or a hydrophobic polymer having a crosslinked gel structure is preferred with a polymer of an alkyl (meth)acrylate being especially preferred. Illustrative of the alkyl (meth)acrylate are methyl (meth)acrylate, ethyl (meth)acrylate, n-butyl (meth)acrylate, isobutyl (meth)acrylate, hexyl (meth)acrylate, octyl (meth)acrylate, 2-ethylhexyl (meth)acrylate, isooctyl (meth)acrylate, decyl (meth)acrylate, isodecyl (meth)acrylate, lauryl (meth)acrylate, and stearyl (meth)acrylate. In particular, use of n-butyl acrylate or 2-ethylhexyl acrylate, which has been widely used as an adhesive component for cataplasma, is preferred.

[0063] Hydrophilic monomers and hydrophobic monomers can be used either singly or in combination. If necessary, a hydrophilic monomer and a hydrophobic monomer can be used in combination

[0064] In the present invention, it is particularly advantageous for the achievement of excellent percutaneous absorption effects for a drug to form the donor 4 into a regular polygonal shape which may be rounded at corners, especially one having 6 or more corners or an oval or circular shape and also to form the receptor 5 into a polygonal shape which may be a round-cornered square shape, especially one having 6 or more corners or a oval or circular shape. Incidentally, an arrangement of the donor 4 and the receptor 5 in a surrounded/surrounding or surrounding/surrounded relationship allows a current to primarily flow through corner portions, so that the distribution of current intensity becomes more even as the number of regular corners in the shape of the donor 4 or receptor 5 increases.

[0065] In the present invention, it is especially preferred for the achievement of excellent percutaneous absorption effects of a drug to arrange a donor and a receptor in a surrounded/surrounding or surrounding/surrounded relationship and also to make the area a skin-contacting portion of the donor or receptor, which is located at the outer peripheral area, 1 to 6 times as large as the area of a skin-contacting portion of the receptor or donor located at the central area.

[0066] In the present invention, it is preferred from the standpoint of storage and management during non-use to peelably cover the surfaces of the adhesive pads 4B,5B with a liner 7. Preferred examples of the liner 7 can be plastic films and a cellulose film.

[0067] The iontophoretic device of this invention constructed as described above can be produced through steps similar to those employed for general medical adhesives such as adhesive plasters and antiphlogistic and analgesic plasters as shown by way of example in the production step flow chart of FIG. 5. A description will next be made about principal steps.

1) Preparation of adhesive base

[0068] Ethylene glycol dimethacrylate (crosslinking agent) and azobisisobutyronitrile (polymerization initiator) are added to 2-hydroxyethyl methacrylate and n-butyl acrylate, and the resultant mixture is subjected to solution polymerization while using dimethylformamide as a polymerization solvent. After the polymerization, an adhesive base is produced through filtration → washing and purification → filtration → drying → grinding → packaging steps.

2) Preparation of drug solution

[0069] In a mixed solvent of a polyhydric alcohol, an alcohol and water, a drug is dissolved only in an amount clinically required as a single dose. At this time, an oil or fat, a fatty acid, a preservative (antiseptic), a stabilizer (antioxidant), a surfactant, a conductivity-imparting substance and a chemical absorption enhancer can be added as needed.

3) Mixing step

[0070] The adhesive base and the drug solution are kneaded at a predetermined mixing ratio.

4) Spreading step

[0071] A mixture, which has been formed in the mixing step, is evenly spread thin on an electrode. Here, the electrode is selected from aluminum (oxide), stainless steel, gold, silver, silver chloride, platinum or platinum black. The thus-spread thickness may be from 0.1 to 1 mm, with 0.2 to 1 mm being particularly preferred.

5) Cutting step

[0072] The electrode with the mixture evenly spread thin thereon is cut by a cutter formed in a desired shape so that at the same time, the electrode and the mixture in an insulating region portion are removed.

6) Backing applying step

[0073] A protective film is applied on a surface of the plaster which has been obtained through the cutting step. An adhesive is coated on an electrode surface, on which a backing cut in the desired shape is adhered. Here, the backing is selected from a plastic sheet, a non-woven fabric or a woven fabric, and a spun lace as a non-woven fabric is particularly preferred. No particular limitation is imposed on the adhesive insofar as it is generally used for medical purposes. However, an acrylic adhesive is preferred.

7) Insulating material coating step

[0074] Portions other than the electrode and the skin-contacting surface of the plaster are coated with an insulating material. No particular limitation is imposed on the insulating material insofar as it is generally used for medical purposes. However, polymers such as polyvinyl chloride, polyesters and butyl rubber are preferred.

8) protective film applying step

[0075] A protective film is applied to a skin-contacting surface of an assembly which has been obtained by mounting the backing on the plaster and coating the portions other than the electrode and the skin-contacting surface of the plaster with the insulating material.

9) Manufacture of power source

[0076] A power source is manufactured through a positive and negative electrode plate forming step, a polymer electrolyte film forming step, an assembly step, a terminal connecting step, an insulating material coating step, an inspection and packaging. In this manufacture process, additional steps may also be incorporated to introduce functions such as switching, frequency control, time control and the like.

[0077] The liner 7 is peeled off from the iontophoretic device of this invention obtained as described above. After the adhesive pads 4B,5B of the donor 4 and receptor 5 are applied to the skin, a current is applied. As is illustrated in the schematic diagram of FIG. 6, a flow of electrons from a cathode (donor) to an anode (receptor) takes place as shown in the schematic diagram of FIG. 6 when indomethacin as an anionic drug is used; for example. By this flow, anions in the cathode are caused to migrate to the anode and on the other hand, cations in the anode are caused to migrate to the cathode, whereby the drug component is percutaneously absorbed.

Examples

[0078] The present invention will hereinafter be described further by the following Examples and Tests.

Example 1

[0079] Using the below-described power source, backing, donor, receptor and liner, an iontophoretic device according to the present invention as shown in FIGS. 1 through 3 was produced in accordance with the production steps illustrated in FIG. 5.

1) Power source

[0080] A single film battery (voltage: 1.5 V or 3 V) was used.

2) Backing

[0081] A non-woven fabric (spun lace: 80 cm^2) was used.

3) Donor and receptor

[0082] Those produced as described below were employed.

(i) Synthesis of adhesive polymer:

[0083] Mixed were 100 g of a blend of 2-hydroxymethyl methacrylate (hereinafter referred to as "HEMA"), n-butyl acrylate (hereinafter referred to as "BA") and ethylene glycol dimethacrylate (hereinafter referred to as "EGDMA") at HEMA:BA:EGDMA = 2:1:0.125 (molar ratio), 0.5 g of 2,2'-azobisisobutyronitrile and 100 g of dimethylformamide. Subsequent to purging with nitrogen gas for deaeration, a polymerization reaction was conducted at 75°C for 15 hours. After stopping of the polymerization reaction, procedures (swelling in isopropyl alcohol → removal of isopropyl alcohol by decantation → washing with deionized water → vacuum drying → grinding) were repeated twice to conduct purification. The thus-purified polymerization product was passed through an 83-mesh sieve, whereby a fine pulverized polymer was obtained.

(ii) Preparation of indomethacin solution:

[0084] Using the formula described in Table 1, indomethacin was dissolved in isopropyl alcohol, followed by the addition of polyethylene glycol 400 and saline to prepare an indomethacin solution.

Table 1

Formula of indomethacin solution	
Indomethacin	1.2 g
Isopropyl alcohol	24 g
Polyethylene glycol 400	49 g

Table 1 (continued)

Formula of indomethacin solution	
Saline	Added to 100 g

(iii) Production of indomethacin-containing adhesive pad:

[0085] With 1 part by weight of the polymer obtained in step (i), 5 parts of the indomethacin solution obtained in step (ii) were mixed. The thus-prepared coating formulation was spread into a mold with 0.5 mm thickness in an amount of 0.1 g per cm^2 between silicone sheets, whereby an indomethacin-containing adhesive pad was produced.

(iv) Electrodes:

[0086] A disc-shaped electrode made of stainless steel was used as a donor electrode, while a doughnut-shaped electrode made of stainless steel was employed as a receptor electrode.

Test 1 - Comparison of indomethacin absorption when the distance from a donor to a receptor (the width of an insulating space region) was changed in the same plane:

[0087] After hair was removed from abdominal regions of Wistar rats (male, 8 weeks old), rectangular donor and receptor adhesive pads produced as in Example 1 were adhered in pairs side by side at varied distances therebetween as illustrated in FIG. 7. By a constant voltage device, a voltage was applied at 4.5 V for 60 minutes. Upon elapsed time of 20, 40 and 60 minutes after starting the voltage application, 1 mℓ blood samples were collected and their concentrations of indomethacin in blood plasma were analyzed by HPLC. Changes in AUC (area under the plasma time change course curve) by the width of the insulating space region are shown in FIG. 8. The AUC tended to increase up to a donor-receptor distance of 2 mm but to decrease at donor-receptor distances of 4 mm and greater.

Test 2 - Comparison of indomethacin absorption between a paired arrangement of a donor and a receptor and a surrounding arrangement of a receptor at an outer peripheral area of a donor, each in the same plane with an insulating space region of 2 mm in width interposed therebetween:

[0088] In a similar manner as in Test 1 except that the shapes and relative positions of donor and receptor having adhesive pads produced as in Example 1 were changed as shown in FIGS. 9(1) and 9(2), a voltage was applied at 3 V for 60 minutes, and the concentrations of indomethacin in blood plasma were analyzed. A comparison of the AUC is shown in FIG. 10. Although the donor and receptor areas and the donor-receptor distance were the same, the surrounding arrangement of the receptor at an outer peripheral area of the donor was greater in AUC.

Test 3 - Comparison of indomethacin absorption among different donor and receptor shapes in the case of surrounding arrangements of receptors at outer peripheral areas of their corresponding donors with insulating space regions of 2 mm in width interposed therebetween:

[0089] In a similar manner as in Test 1 except that the shapes and relative positions of donor and receptor having adhesive pads produced as in Example 1 were changed as shown in FIGS. 11(1) to 11(4), a current was applied at 0.16 mA for 60 minutes, and the concentration of indomethacin in blood plasma were analyzed. A comparison of the AUC is shown in FIG. 12. The AUC increased as the number of corners increased in the order of a triangle, a square and a hexagon. No substantial difference was however observed between the hexagon and a circle.

Test 4 - Comparison in indomethacin absorption between a surrounding arrangement of a receptor at an outer peripheral area of a donor and a surrounding arrangement of a donor of the same area as the first-mentioned donor at an outer peripheral area of a receptor of the same area as the first-mentioned receptor, each in the same plane with an insulating space region of 2 mm in width interposed therebetween:

[0090] In a similar manner as in Test 1 except that the shapes and relative positions of donor and receptor were changed as shown in FIGS. 13(1) and 13(2), a voltage was applied at 3 V for 60 minutes, and the concentrations of indomethacin in blood plasma were analyzed. A comparison of the AUC is shown in FIG. 14. The AUC was substantially the same.

Example 2

[0091] An iontophoretic device according to the present invention was produced in a similar manner as in Example 1 except that a lidocaine solution of the formula shown in Table 2 was employed as donor and receptor solutions.

Table 2

Formula of lidocaine solution	
Lidocaine	5 g
Polyethylene glycol 400	80 g
Saline	Added to 100 g

Test 5 - Comparison in lidocaine absorption between a paired arrangement of a donor and a receptor and a surrounding arrangement of a receptor at an outer peripheral area of a donor, each in the same plane with an insulating space region of 2 mm in width interposed therebetween:

[0092] After hair was removed from abdominal regions of Wistar rats (male, 8 weeks old), lidocaine-containing, donor and receptor adhesive pads produced as in Example 2 were adhered in such shapes and arrangements as illustrated in FIGS. 15(1) and 15(2). By a constant voltage device, a voltage was applied at 3 V for 180 minutes. Upon elapsed time of 60, 120 and 180 minutes after starting the voltage application, 1 mℓ blood samples were collected and their concentrations of lidocaine in blood plasma were analyzed by HPLC. A comparison of the AUC is shown in FIG. 16. The surrounding arrangement of the receptor at the outer peripheral area of the donor was clearly higher in AUC.

Test 6 - Comparison in indomethacin absorption between a polygon and a regular polygon:

[0093] After hair was removed from abdominal regions of Wistar rats (male, 8 weeks old), donors and receptors - which were composed of stainless steel electrodes and adhesive pads (produced as in Example 1) and were in the shapes and arrangements shown in FIGS. 17(1) and 17(2) - were adhered with insulating space regions of 2 mm in width interposed therebetween. They were fixed by surgical tapes, and each cathode (donor), its corresponding anode (receptor) and a constant voltage device were connected together by lead wires. A voltage was applied at 4.5 V for 60 minutes. Upon elapsed time of 20, 40 and 60 minutes after starting the voltage application, 1 mℓ blood samples were collected and their concentrations of indomethacin in blood plasma were analyzed by HPLC. A comparison in AUC between the polygon (octagon) and the regular polygon (regular octagon) is shown in FIG. 18. Although the donor and receptor areas and the insulating regions were of the same length, the regular polygon was clearly higher in AUC.

Test 7 - Comparison in indomethacin absorption between a space and an adhesive tape as an insulating region of 2 mm in width in the case of a regular polygon:

[0094] When the insulating region was the space, the concentrations of indomethacin were analyzed in a similar manner as in Test 6 except that donors and receptors - which were composed of stainless steel electrodes and pads and were in the shapes and arrangements shown in FIGS. 19(1) and 19(4) - were used and the voltage application conditions were set at 3 V - 60 minutes. When the insulating region was the adhesive tape, on the other hand, the concentrations of indomethacin in blood plasma were analyzed in a similar manner as in the case of the space as the insulating region except that a silicone rubber with 0.5 mm thickness was placed at the insulating region and a double-tack tapes ("NICE TACK", trade name; product of Nichiban Co., Ltd.) were used at contacting areas to the skin. A comparison in AUC between the case of the space as the insulating region and the case of the adhesive tape as the insulating region is shown in FIG. 20. In the case of the space as the insulating region, the AUC increased with the number of corners in the polygon, achieving the highest AUC in the case of the circle. According to the comparison between the space an the adhesive tape as the insulating area, the space was higher in AUC in any one of the regular polygons. This difference tended to become greater as the number of corners increased.

Test 8 - Adhesion tests of pads:

[0095] The indomethacin-containing adhesive pad (2 cm x 2 cm x 0.5 cm thick) produced in Example 1 and an indomethacin-containing agar pad (2 cm x 2 cm x 0.5 cm) disclosed in JP Kokai No. 7-185016 were each placed on a slide glass which was mounted on a movable table of "RHEO METER" (Model: NRM-3002D-L; manufactured by Fudo Kogyo K.K.) shown in FIG. 21. After a cover glass (1.8 cm x 1.8 cm; area: 3.24 cm^2) attached to an adaptor was pressed until a load of 250 g was applied on the pad, the instrument was left over for 10 seconds and the movable table was moved at a speed of 2 cm/min to peel off the pad. A load at the time of peeling-off was measured. A comparison in peel strength between the agar pad and the indomethacin-containing pad produced in Example 1 is shown in FIG. 22. The indomethacin-containing pad was clearly higher in peel strength and, when adhered on a human forearm, did not separate. In contrast, the agar pad was low in peel strength and, when adhered on a forearm, separated shortly.

Test 9 - Comparison in indomethacin absorption between a single receptor and plural receptors:

[0096] Plasma indomethacin levels were analyzed in a similar manner as in Test 6 except that the voltage application conditions were set at 3 V - 60 minutes and the donors and receptors - which were composed of electrodes and adhesive pads and were in the shapes and arrangements shown in FIGS. 23(1) and 23(4) - were used with insulating space regions of 2 mm in width interposed therebetween. A comparison in AUC between the single receptor and the plural receptors is shown in FIG. 24. The AUC was substantially equal irrespective of the number of receptor(s).

Test 10 - Comparison of indomethacin absorption among different distances from a donor to a receptor in a concentric arrangement:

[0097] The concentrations of indomethacin in blood plasma were analyzed in a similar manner as in Test 6 except that the voltage application conditions were set at 3 V - 60 minutes and donors and receptors - which were composed of electrodes and adhesive pads and were in the shapes and arrangements shown in FIGS. 25(1) and 25(4) - were used with insulating space regions of 0.5 mm, 2 mm, 5 mm and 10 mm in width interposed therebetween. A comparison of AUC among the insulating regions of the different widths in the concentric arrangement is shown in Table 26. The AUC reached the maximum when the width of the insulating space region was 2 mm.

Test 11 - Comparison of indomethacin absorption among different receptor/donor area ratios in a concentric arrangement:

[0098] Plasma indomethacin levels were analyzed in a similar manner as in Test 6 except that the voltage application conditions were set at 3 V - 60 minutes and donors and receptors - which were composed of electrodes and adhesive pads, were in the shapes and arrangements shown in FIGS. 27(1) through 27(6), and had receptor/donor area ratios of 0.5, 1, 2, 3, 4 and 5 - were used with insulating space regions of 2 mm in width interposed therebetween. A comparison of the AUC among the different receptor/donor area ratios in the concentric arrangement is shown in FIG. 28. The AUC apparently increased up to the area ratio of 3, but no substantial changes were observed beyond that area ratio.

Test 12 - Comparison of lidocaine absorption among different area ratios of a receptor (outer peripheral part) to a donor (inner central part):

[0099] The concentrations of lidocaine in blood plasma were analyzed in a similar manner as in Test 5 except that donors and receptors - which were composed of electrodes of the shapes as shown in FIGS. 29(1) to 29(3) and lidocaine-containing donor and receptor adhesive pads produced as in Example 2 and had receptor/donor area ratios of 1, 3 and 5 - were used and arranged as shown in the same drawings. A comparison of the AUC among the different receptor/donor area ratios in the concentric arrangement is shown in FIG. 30. The AUC increased up to the area ratio of 3, but no substantial changes were observed beyond that area ratio.

Test 13 - Comparison of lidocaine absorption among different area ratios of a receptor (inner central part) to a donor (outer peripheral part) in a concentric arrangement:

[0100] Employed were donors and receptors, which were composed of electrodes of the shapes shown in FIGS. 31(1) to 31(4) and lidocaine-containing donor and receptor adhesive pads produced as in Example 2 and had receptor/donor area ratios of 0.17, 0.33, 0.5 and 1. The donors and receptors were arranged as shown in the same drawings, and stainless steel electrodes of the same shapes as the pads were attached. A voltage was applied at 3 V for 40 minutes by a constant voltage device.

[0101] After stopping the voltage application, the pads were peeled off and skins were then wiped with 70% alcohol. Skin samples were excised from the pad-adhered parts, and the amounts of lidocaine permeated into the skins were analyzed by HPLC. Comparison results are shown in FIG. 32.

[0102] The amount of lidocaine permeated increased with the receptor/donor area ratio when the area of the donor and the width of the insulating region were the same.

Test 14 - Comparison in lidocaine absorption between a receptor (inner central part) and a donor (outer peripheral part) having the same shape and those having different shapes:

[0103] Electrodes of the shapes shown in FIGS. 33(1) to 33(2) and lidocaine-containing donor and receptor adhesive pads produced as in Example 2 were adhered to hair-removed abdominal regions of rats. Stainless steel electrodes of the same shapes as the corresponding pads were attached. A voltage was applied at 3 V for 20 minutes by a constant voltage device.

[0104] After stopping the voltage application, the amount of lidocaine permeated in the skin was analyzed by HPLC in a similar manner as in Test 13. Their comparison is shown in FIG. 34.

[0105] The amount of lidocaine permeated was greater in the case of the square peripheral part when the areas of the receptor and the insulating region were the same.

Test 15 - Comparison of lidocaine absorption among a square donor with unrounded corners and square donors with rounded corners in the combinations of circular receptors (inner central parts) and the square donors (outer peripheral part):

[0106] Electrodes of the shapes shown in FIGS. 35(1) to 35(5) and lidocaine-containing donor and receptor adhesive pads produced as in Example 2 were adhered to hair-removed dorsal regions of guinea pigs. Stainless steel electrodes of the same shapes as the corresponding pads were attached. A voltage was

applied at 3 V for 120 minutes by a constant voltage device.

[0107] After stopping the voltage application, the amount of lidocaine permeated in the skin was analyzed by HPLC in a similar manner as in Test 13. Comparison results are shown in FIG. 36.

[0108] The amount of lidocaine permeated was substantially equal among the case of the square outer peripheral part and the cases of the square peripheral parts with the corners thereof rounded at radii of up to 10 mm.

Capability of Exploitation in Industry

[0109] The present invention can provide am iontophoretic device, which permits safe and efficient percutaneous absorption of a drug without increasing a current value and also features extremely good handling ease.

Claims

1. An iontophoretic device for the electric percutaneous administration of a drug, comprising: a backing provided with a power source, and a donor and a receptor arranged on the same one side of said backing with an insulating space region interposed therebetween, whereby said device has an integral structure.

2. An iontophoretic device according to claim 1, wherein said receptor is arranged surrounding an outer peripheral part of said donor or said donor is arranged surrounding an outer peripheral part of said receptor, with said insulating space region interposed therebetween.

3. An iontophoretic device according to claim 1 or 2, wherein said insulating space region interposed between said receptor and said donor has a width of from 0.5 to 12 mm.

4. An iontophoretic device according to any one of claims 1-3, wherein said donor is provided on one of sides of an electrode plate with an adhesive pad containing a solution of said drug or said drug and an electrolyte solution, and said receptor is provided on one of sides of an electrode plate with an adhesive pad containing said drug and an electrolyte solution or an electrolyte solution.

5. An iontophoretic device according to any one of claims 1-4, wherein said donor and said receptor are in the form of regular polygonal shapes which may be round-cornered square shapes, oval shapes or circular shapes.

6. An iontophoretic device according to any one of claims 1-5, wherein said donor and said receptor is in a surrounding/surrounded or surrounded/surrounding arrangement relationship, and an area of a skin-contacting portion of said outer peripheral part is 1 to 6 times as large as an area of a skin-contacting portion of said inner central part.

7. An iontophoretic device according to any one of claims 1-6, wherein said drug is a protein or peptide preparation, an antipyretic, antiphlogistic and analgesic agent, a steroidal antiphlogistic, a vasodilator, an antihypertensive and antiarrhythmic agent, an antihypertensive agent, an antitussive expectorant, an antitumor agents, a local anesthetic, a hormonal agent, an antiallergic agents, an antihistamic agent, an anticoagulant, an antispasmodic, a cerebral circulation and metabolism improver, an antidepressant anxiolytic, a vitamin D preparation, a hypoglycemic, an antiulcerative agent, a hypnotic, an antibiotic, an antifungal agent, a sedative, a bronchodilator, a virucide, a dysuria treating agent, or a parasympathomimetics.

8. An iontophoretic device according to any one of claims 1-7, wherein said adhesive pads are made of polyvinyl alcohol, polyurethane, or crosslinked copolymer of at least two esters selected from glucosyloxyalkyl (meth)acrylates, hydroxyalkyl (meth)acrylates or alkyl (meth)acrylates.

9. An iontophoretic device according to any one of claims 1-8, wherein said electrodes are made of one or two metals selected from aluminum, stainless steel, gold, silver, silver chloride, platinum or platinum black.

10. An iontophoretic device according to any one of claims 1-9, wherein said backing comprises any one of polyethylene, polypropylene, ethylene-vinyl acetate copolymer, vinylon, polyester, polyurethane and nylon sheets, non-woven rayon and polyesters fabrics, and woven polyester, acrylic resin, silk and cotton fabrics.

11. An iontophoretic device according to any one of claims 1-10, wherein said power source is a button battery, a cylindrical battery or a film battery.

12. An iontophoretic device according to any one of claims 1-11, wherein said adhesive pads are peelably covered at surfaces thereof with liners.

13. An iontophoretic device according to claim 12, wherein said liners are plastic films or cellulose films.

Fig. 1

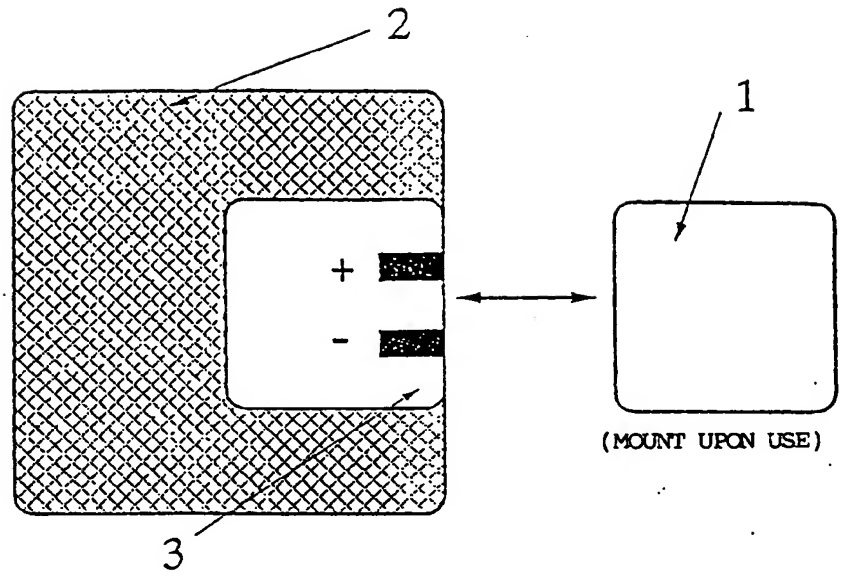


Fig. 2

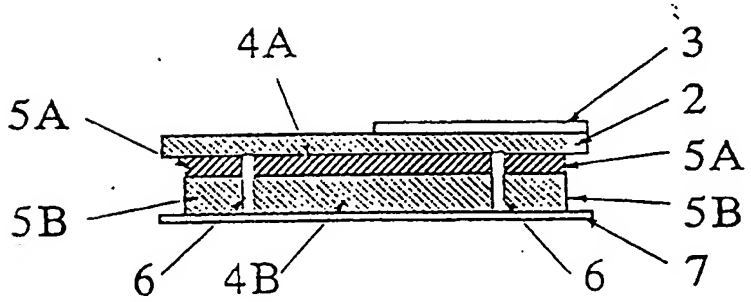


Fig. 3

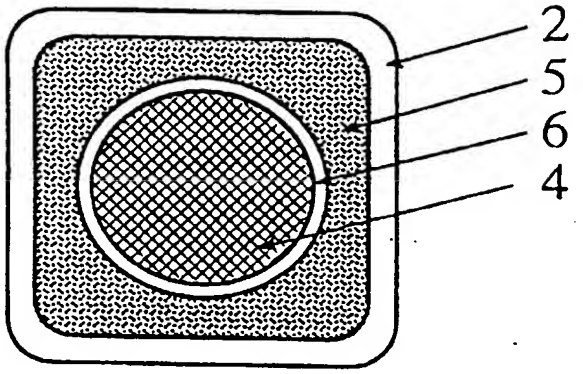


Fig. 4

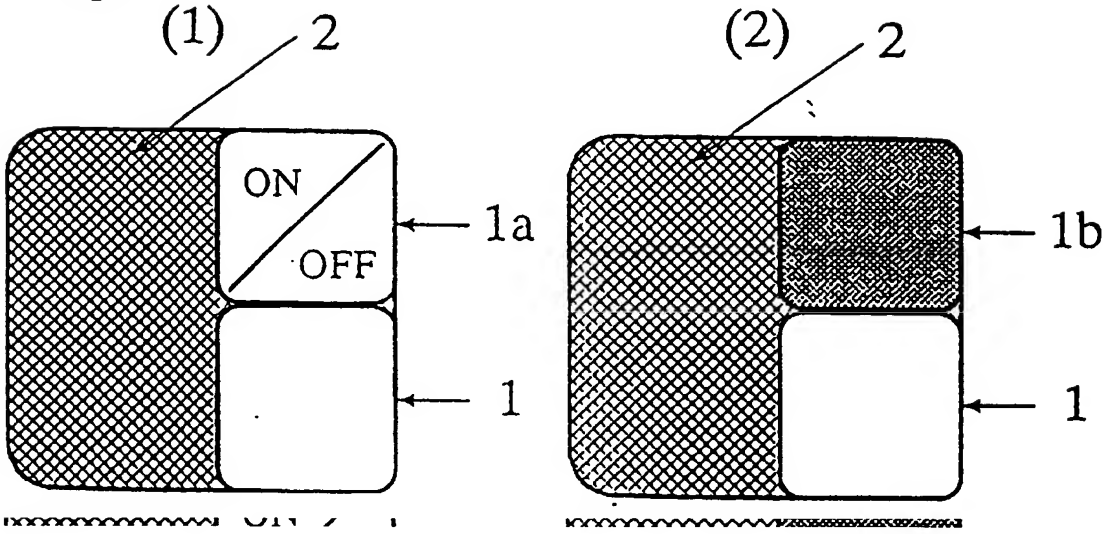


Fig. 5

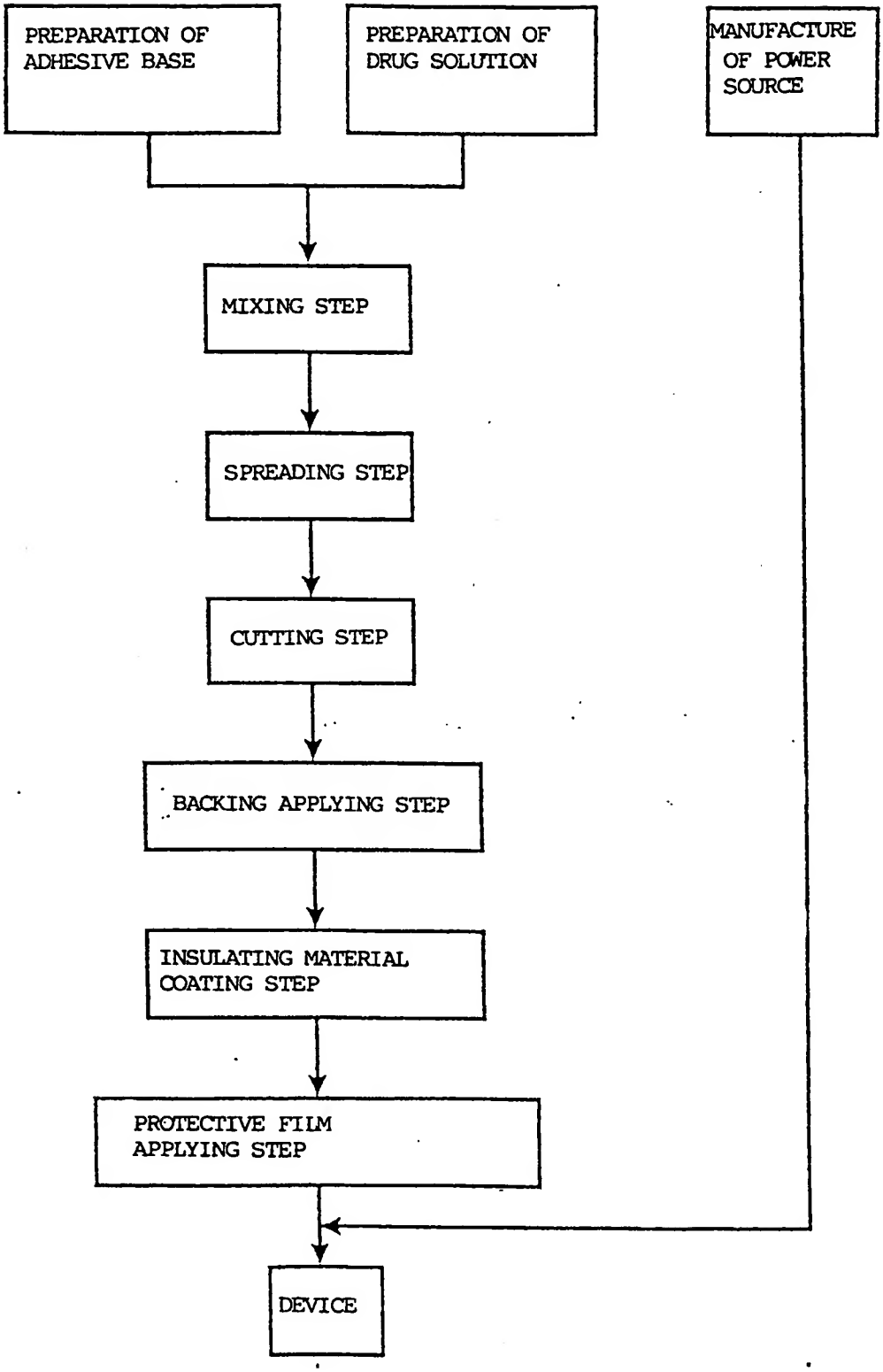

PREPARATION OF ADHESIVE BASE
PREPARATION OF DRUG SOLUTION
MANUFACTURE OF POWER SOURCE
MIXING STEP
SPREADING STEP
CUTTING STEP
BACKING APPLYING STEP
INSULATING MATERIAL COATING STEP
PROTECTIVE FILM APPLYING STEP
DEVICE

Fig. 6

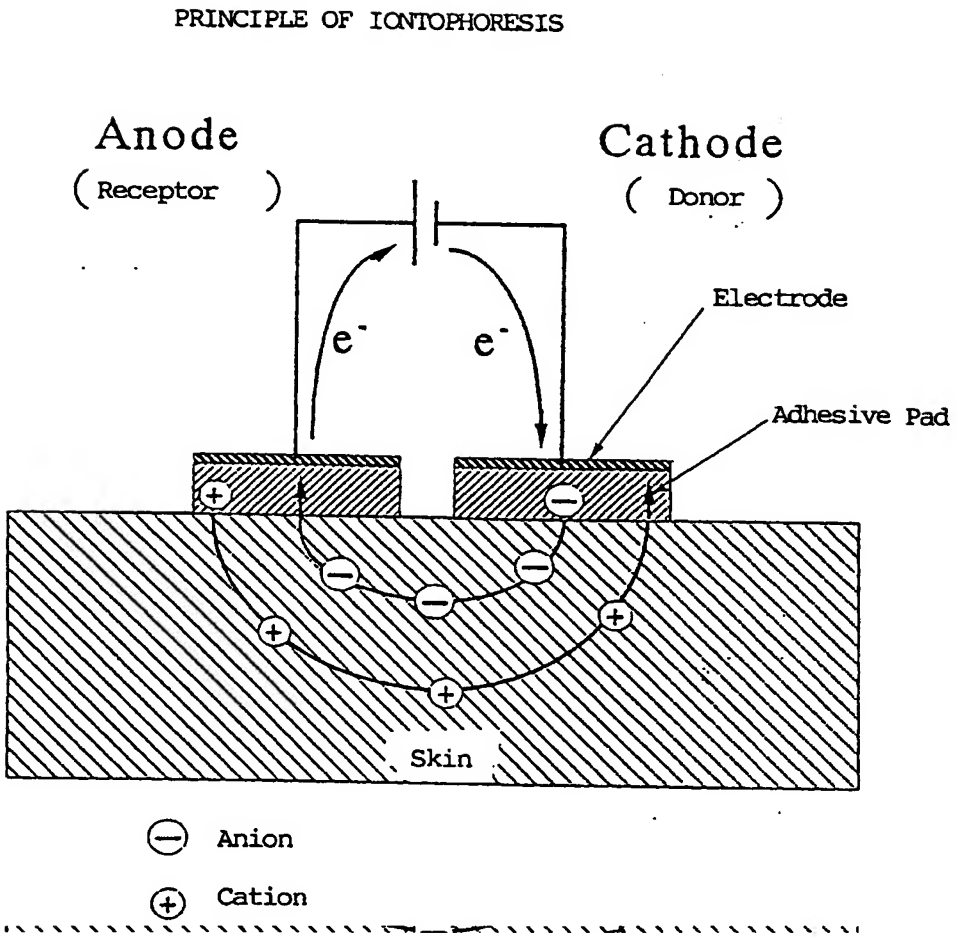
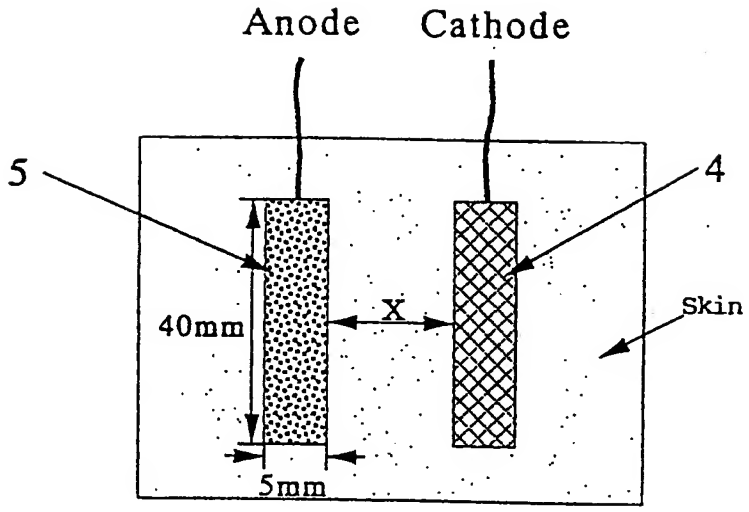

PRINCIPLE OF IONTOPHORESIS
Anode
(Receptor)
Cathode
(Donor)
e-
e-
Electrode
Adhesive Pad
Skin
Anion
Cation

Fig. 7



X : 0.5,1,2,4,6,8,10 and 12 mm

Fig. 8

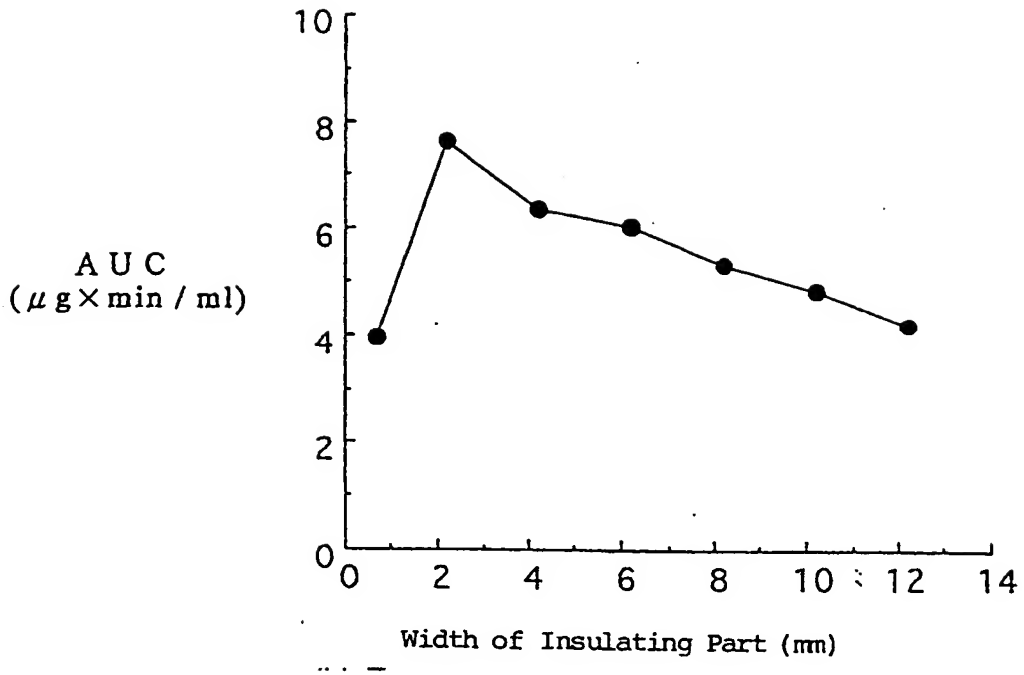

AUC
(μg×min / ml)
10
8
6
4
2
0
0
2
4
6
8
10
12
14
Width of Insulating Part (mm)

Fig. 9

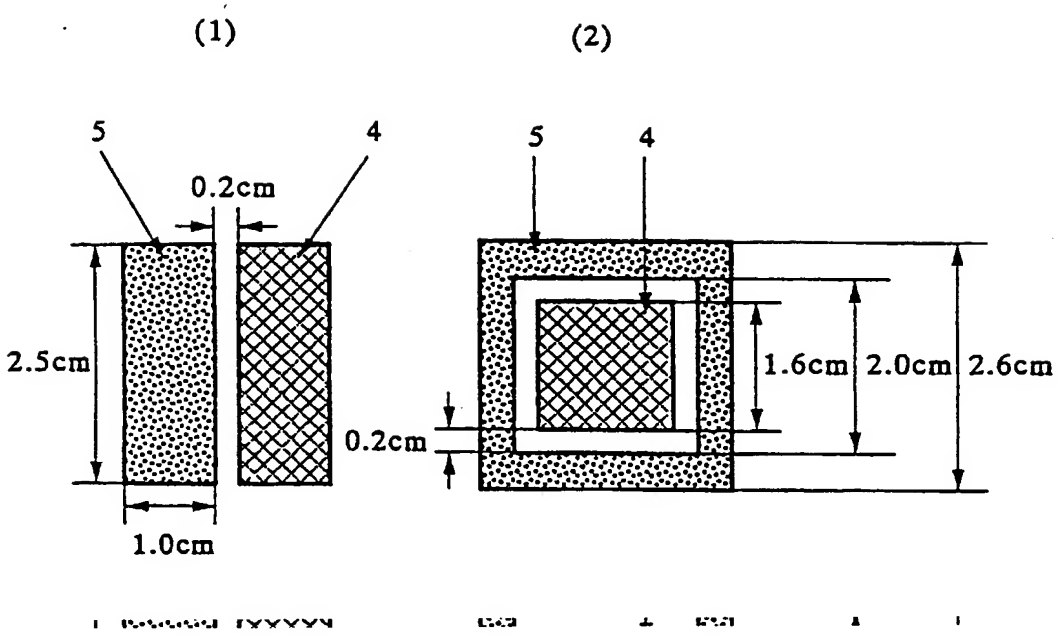
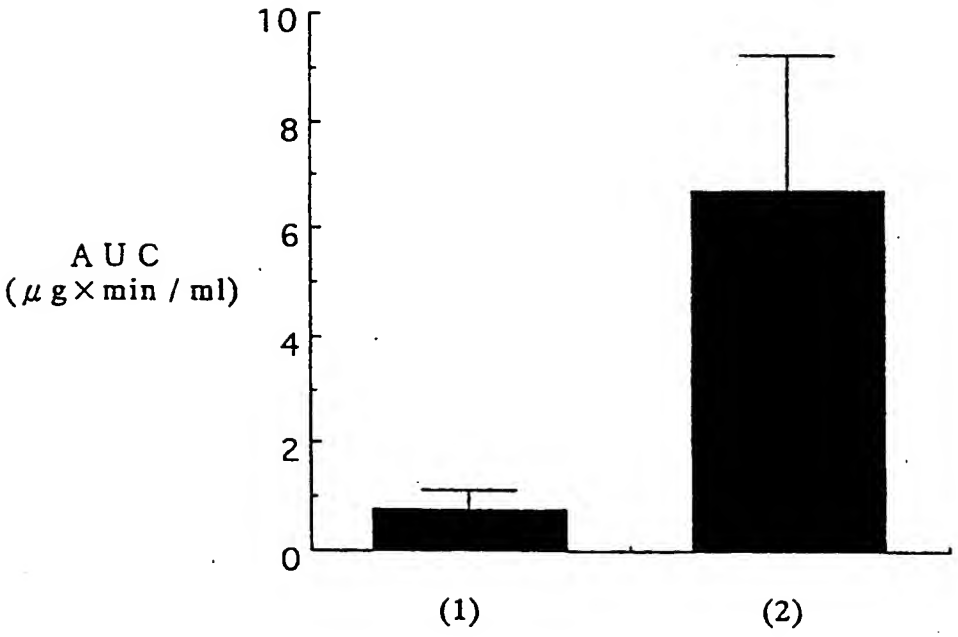


Fig. 10



(n=3 ; mean±S.E.)

Fig. 11

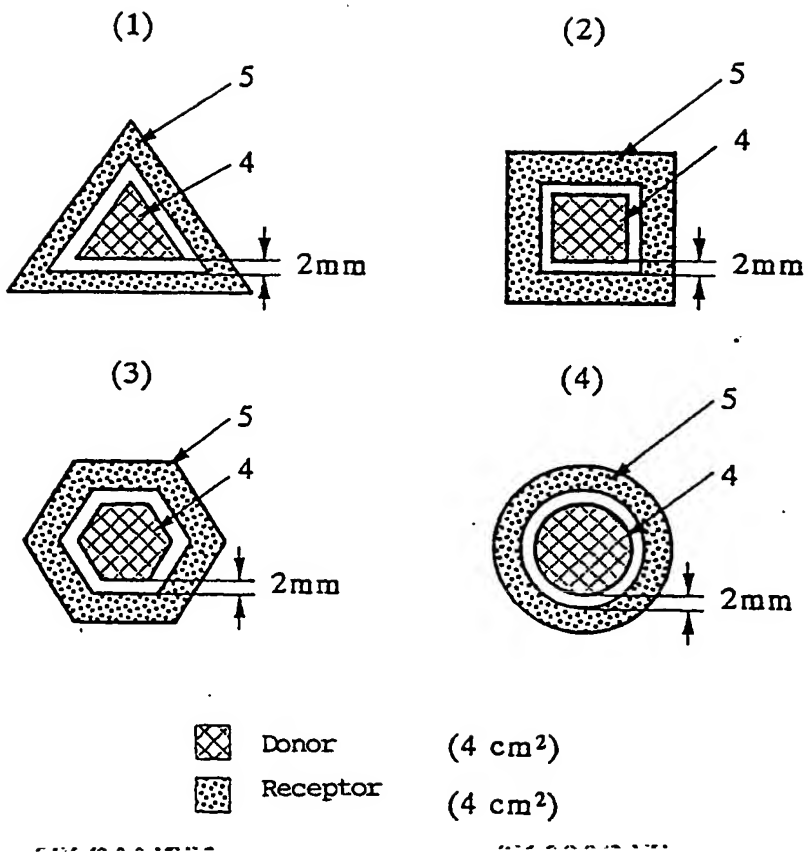


Fig. 12

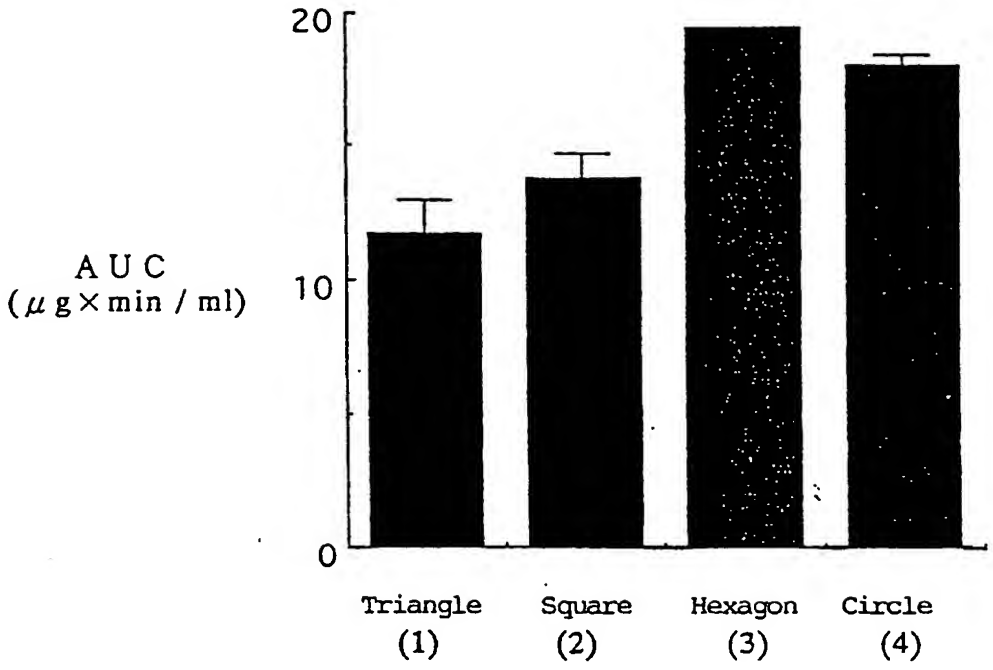

AUC
(μg×min / ml)
20
10
0
Triangle
(1)
Square
(2)
Hexagon
(3)
Circle
(4)
(n=3 ; mean±S.E.)

Fig. 13

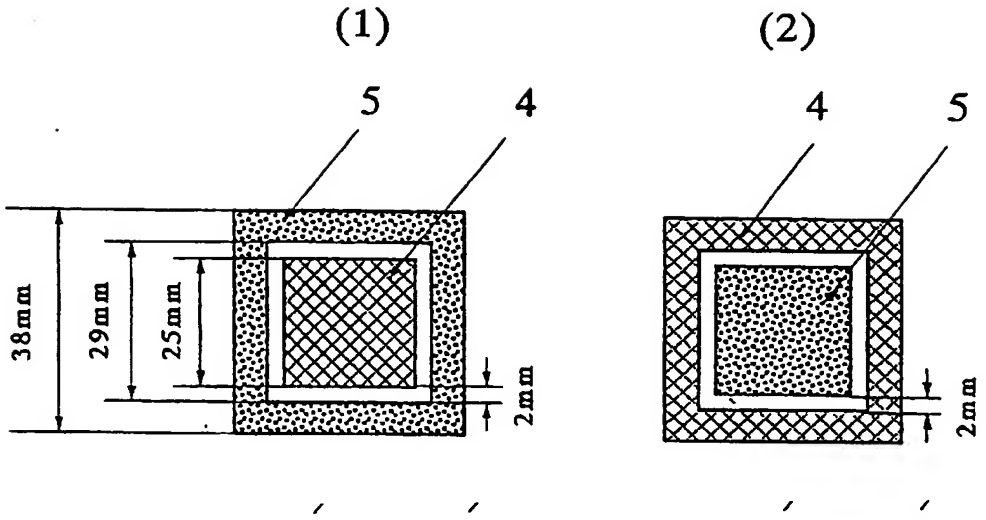
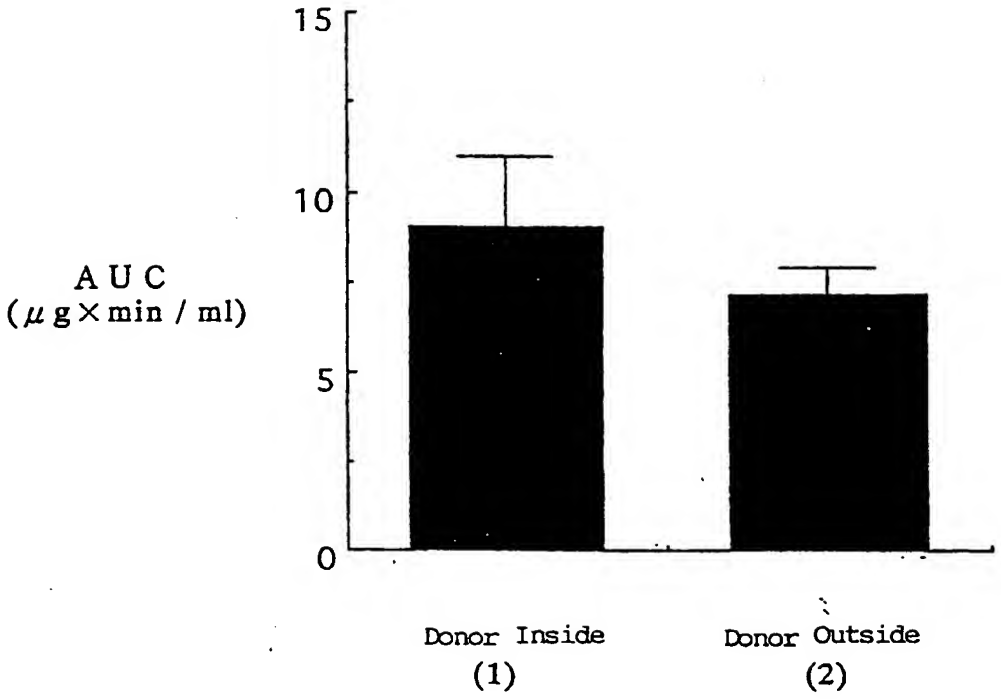


Fig. 14



(n=3 ; mean±S.E.)

Fig. 15

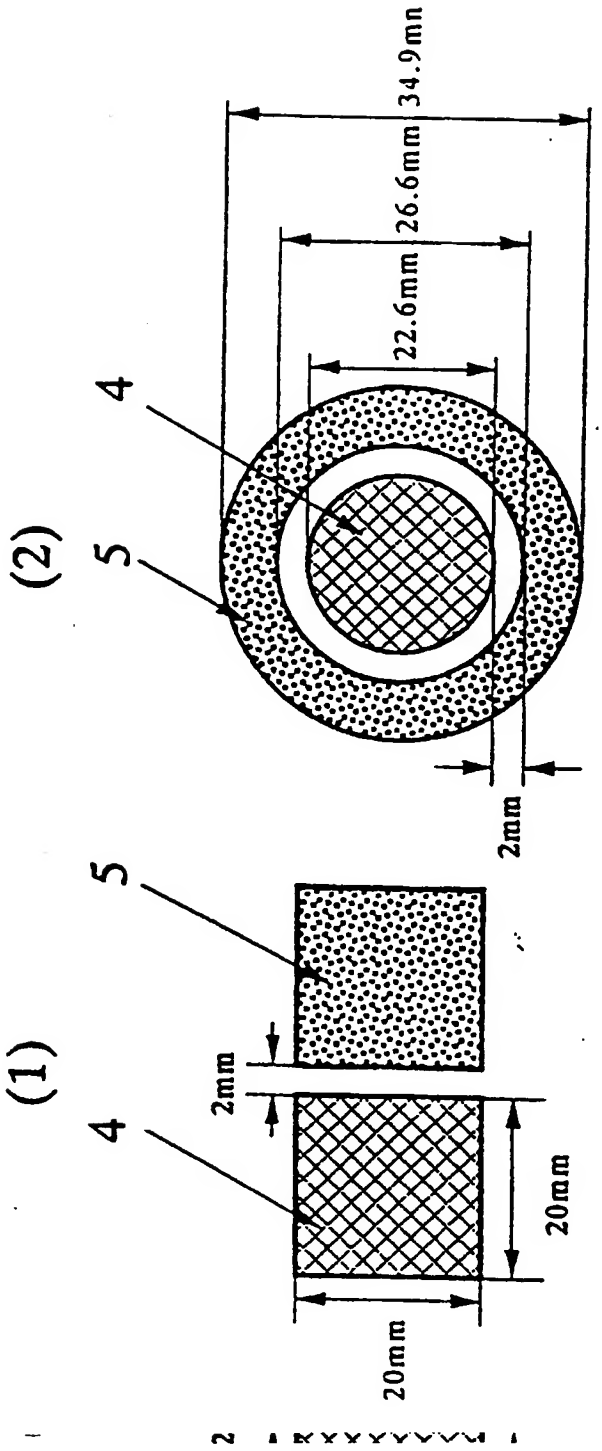


Fig. 16

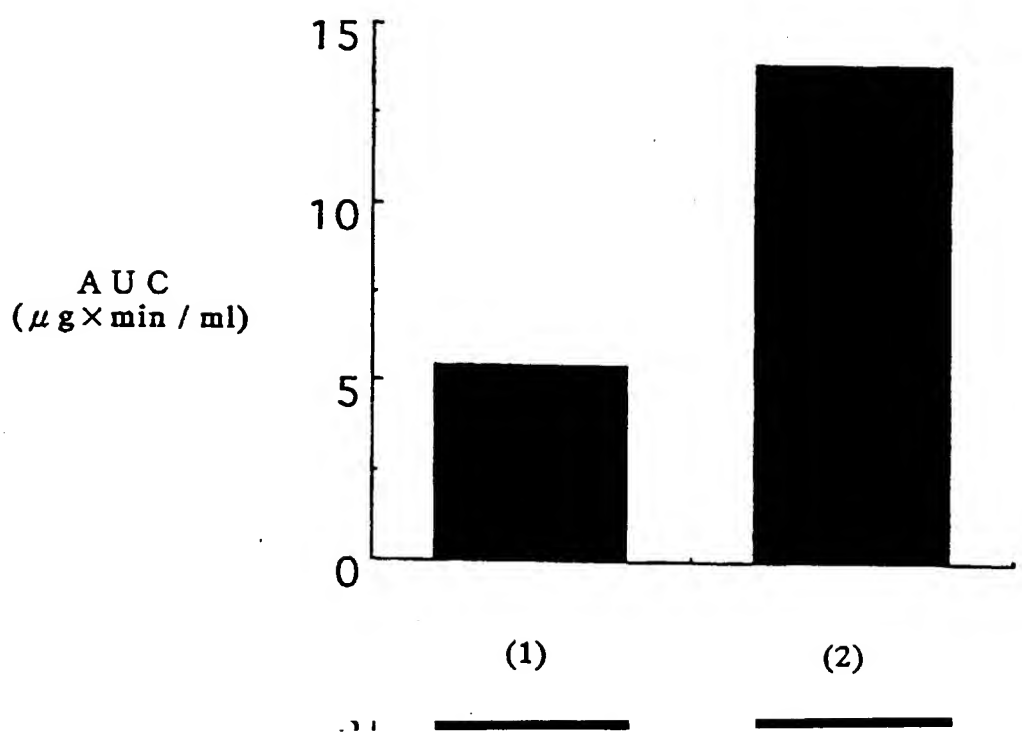


Fig. 17

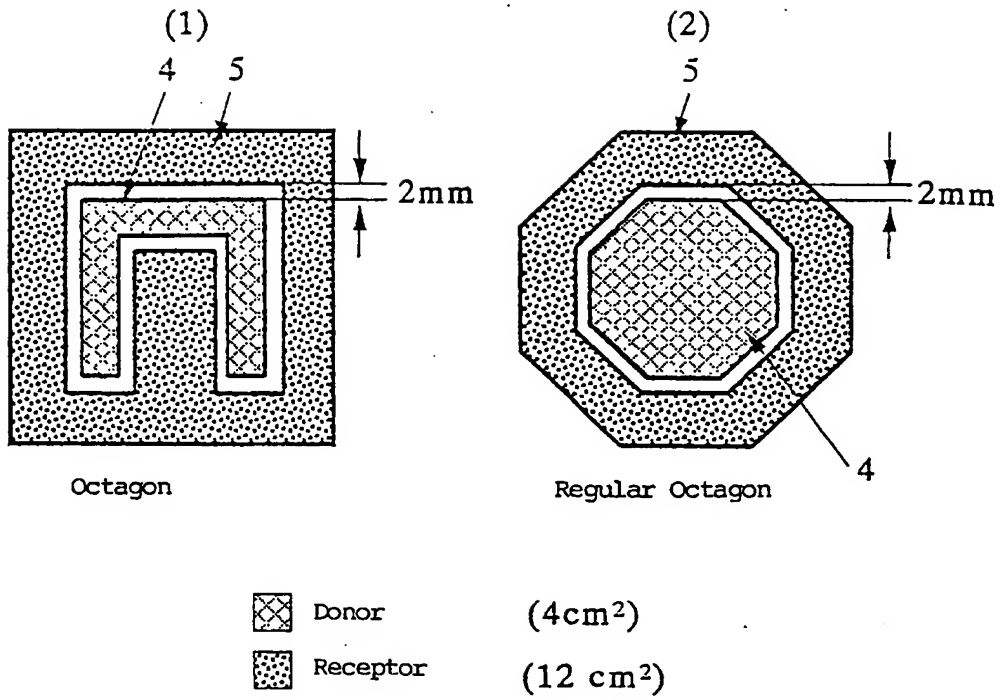

(1)
4
5
2mm
Octagon
(2)
5
2mm
4
Regular Octagon
Donor (4cm²)
Receptor (12 cm²)

Fig. 18

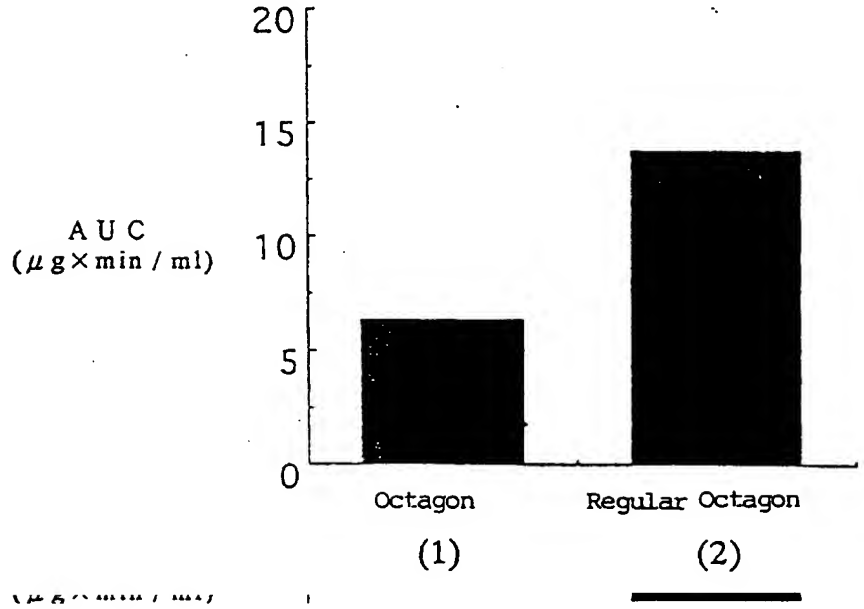

AUC
(μg×min / ml)
20
15
10
5
0
Octagon
Regular Octagon
(1)
(2)

Fig. 19

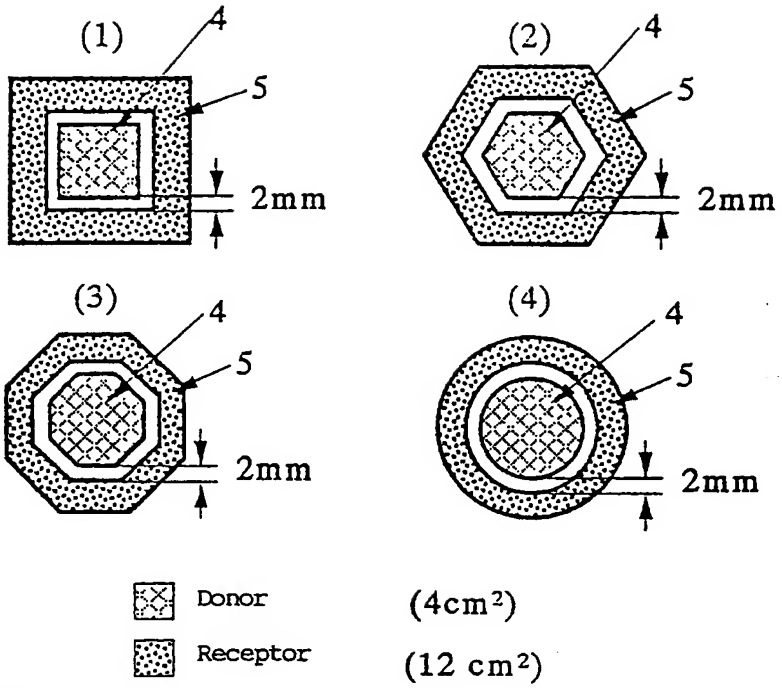

(1)
4
5
2mm
(2)
4
5
2mm
(3)
4
5
2mm
(4)
4
5
2mm
Donor
(4cm²)
Receptor
(12 cm²)

Fig. 20

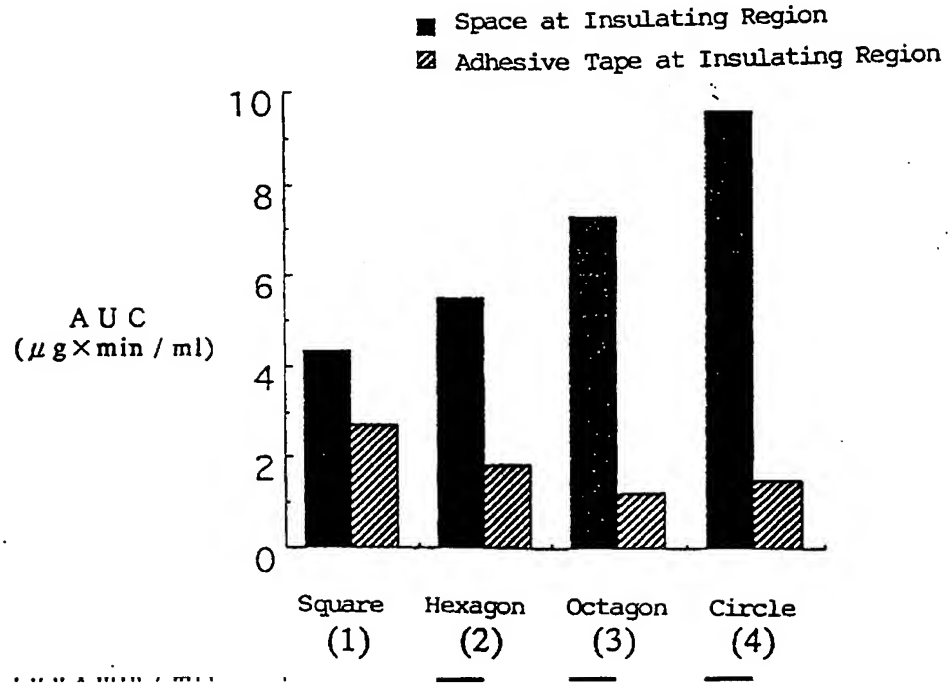
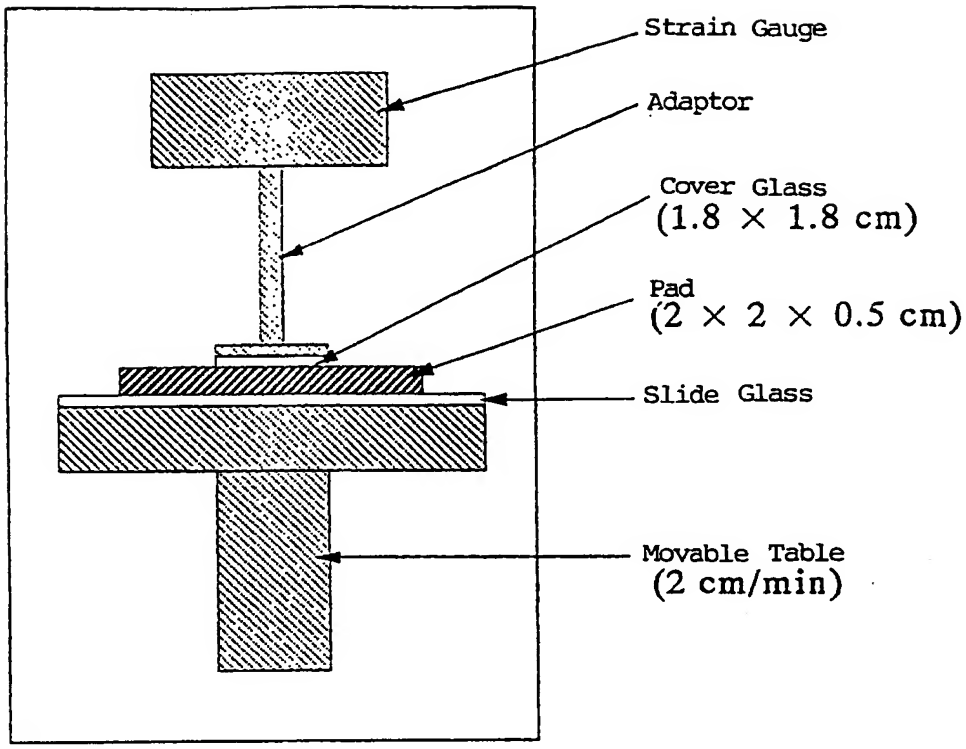

Space at Insulating Region
Adhesive Tape at Insulating Region
AUC
(μg×min / ml)
10
8
6
4
2
0
Square
(1)
Hexagon
(2)
Octagon
(3)
Circle
(4)

Fig. 21



RHEO METER
MODEL NRM-3002D-L

Fig. 22

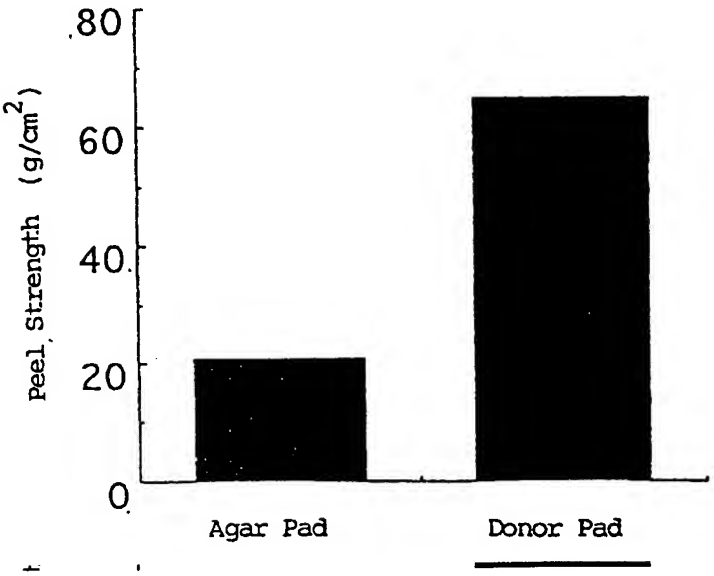


Fig. 23

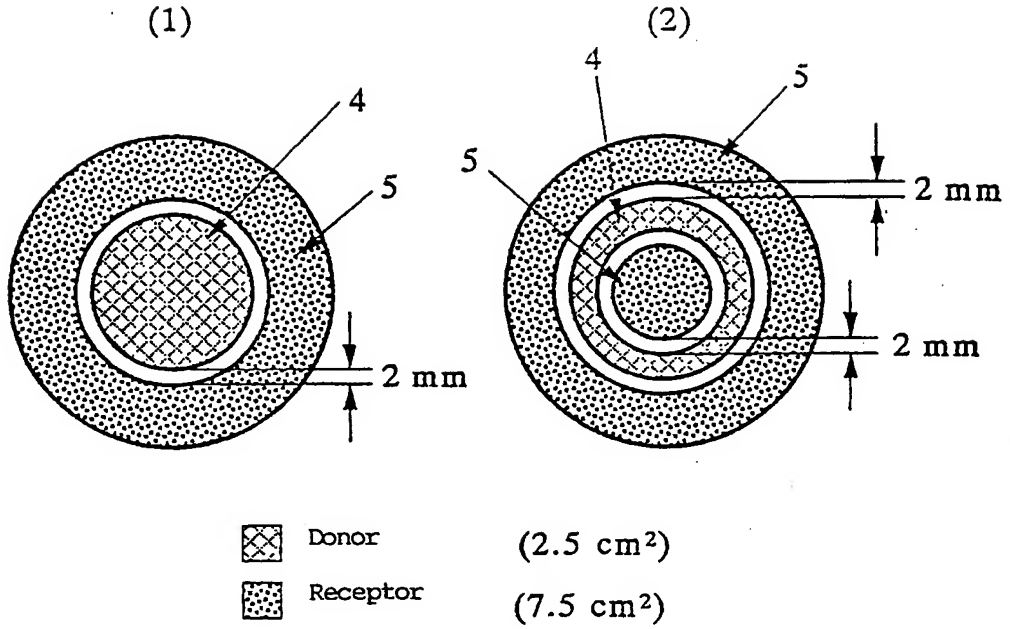
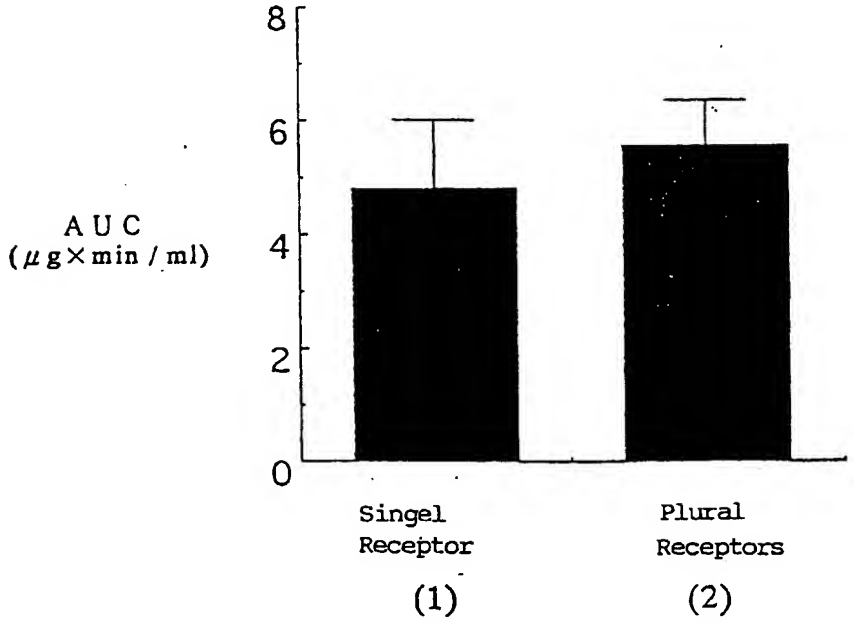


Fig. 24



(n=3 ; mean ± S.E.)

Fig. 25

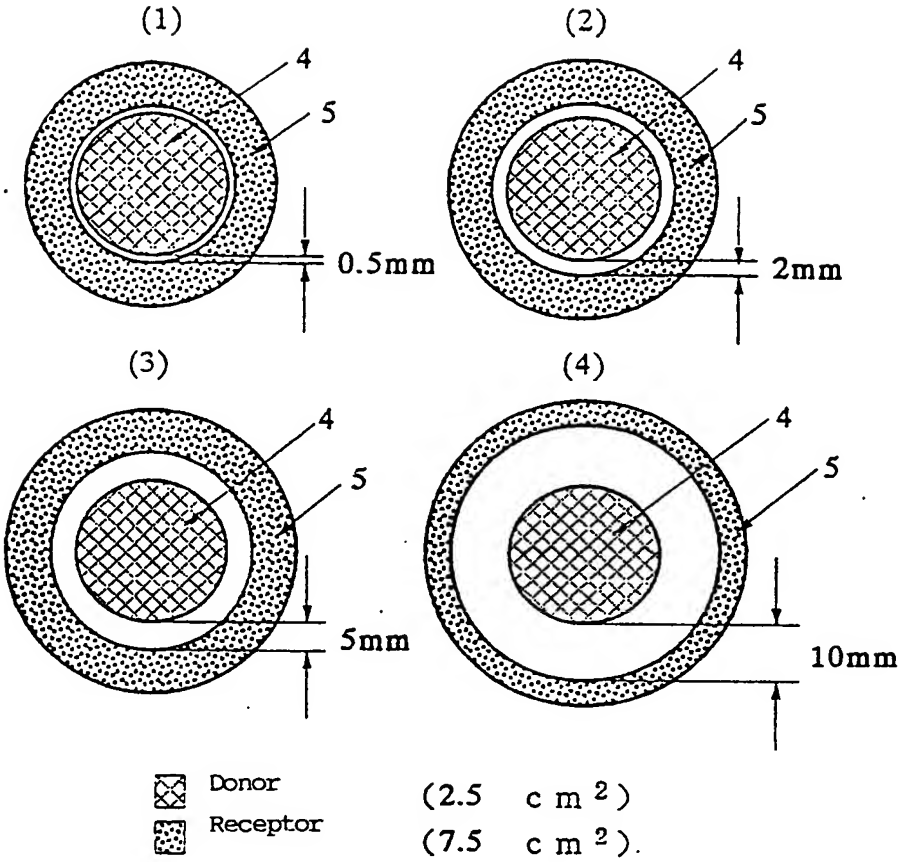

(1)
4
5
0.5mm
(2)
4
5
2mm
(3)
4
5
5mm
(4)
4
5
10mm
Donor
Receptor
(2.5 c m 2)
(7.5 c m 2).

Fig. 26

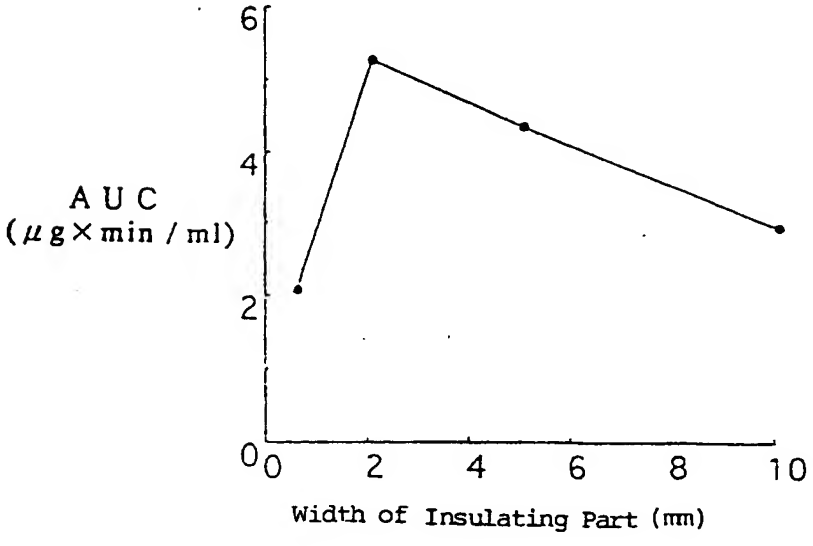

AUC
(μg×min / ml)
6
4
2
0
0
2
4
6
8
10
Width of Insulating Part (mm)

Fig. 27

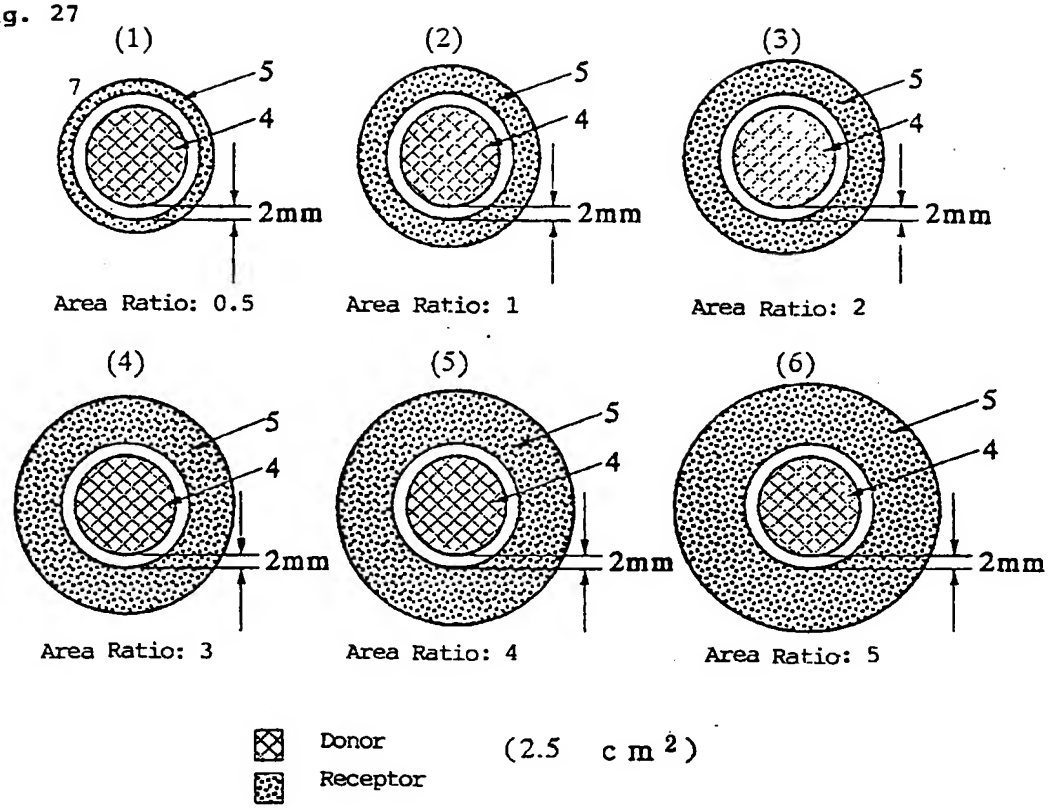

(1)
(2)
(3)
(4)
(5)
(6)
7
5
4
2mm
Area Ratio: 0.5
Area Ratio: 1
Area Ratio: 2
Area Ratio: 3
Area Ratio: 4
Area Ratio: 5
Donor
Receptor
(2.5 cm²)

Fig. 28

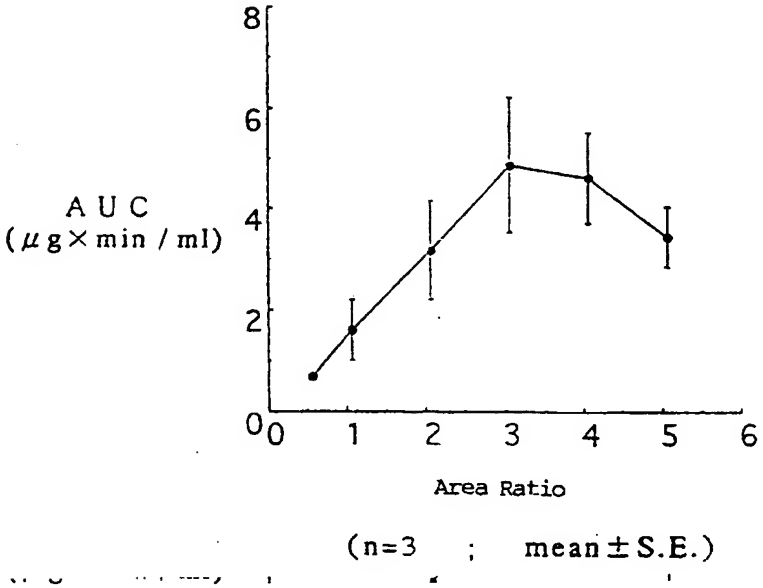

AUC
(μg×min / ml)
8
6
4
2
0
0
1
2
3
4
5
6
Area Ratio
(n=3 ; mean±S.E.)

Fig. 29

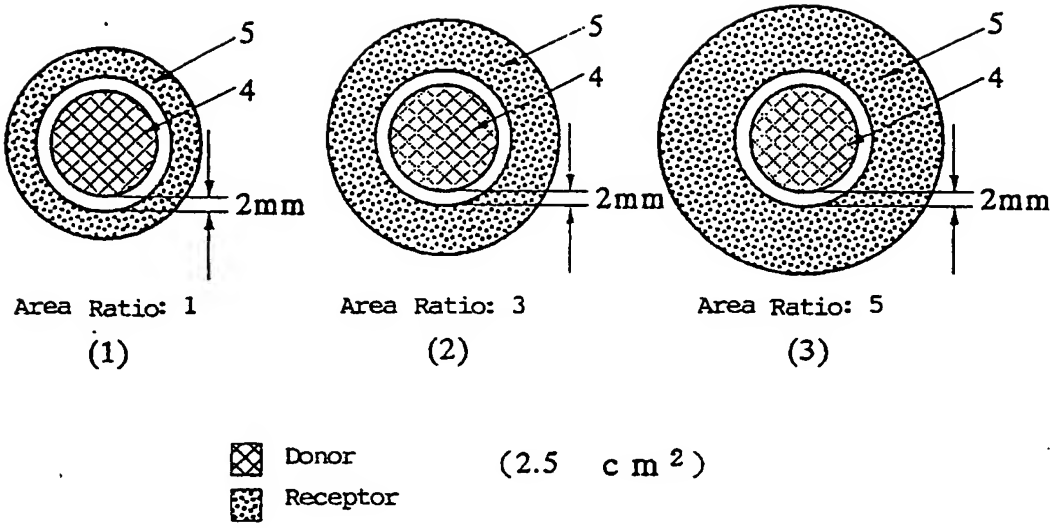

5
4
2mm
Area Ratio: 1
(1)
Area Ratio: 3
(2)
Area Ratio: 5
(3)
Donor
Receptor
(2.5 cm²)

Fig. 30

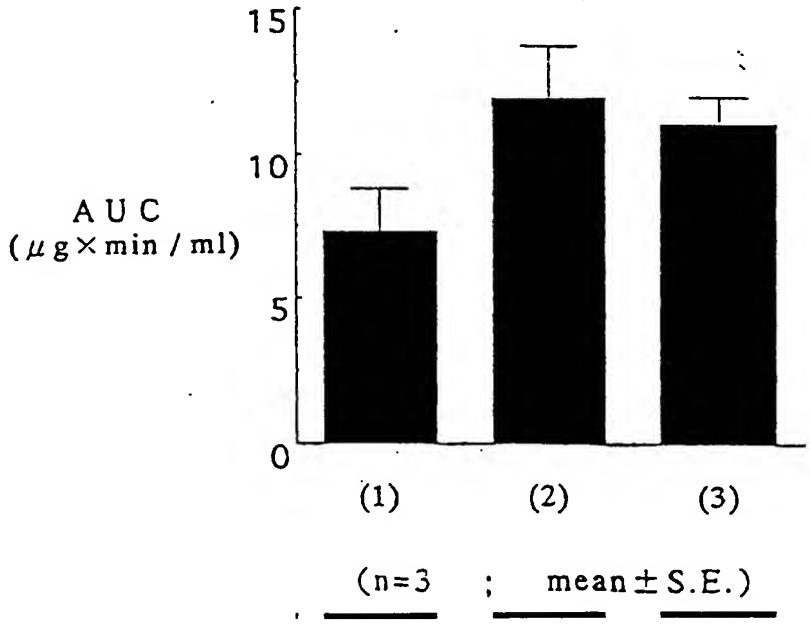

AUC
(μg×min / ml)
15
10
5
0
(1)
(2)
(3)
(n=3 ; mean±S.E.)

Fig. 31

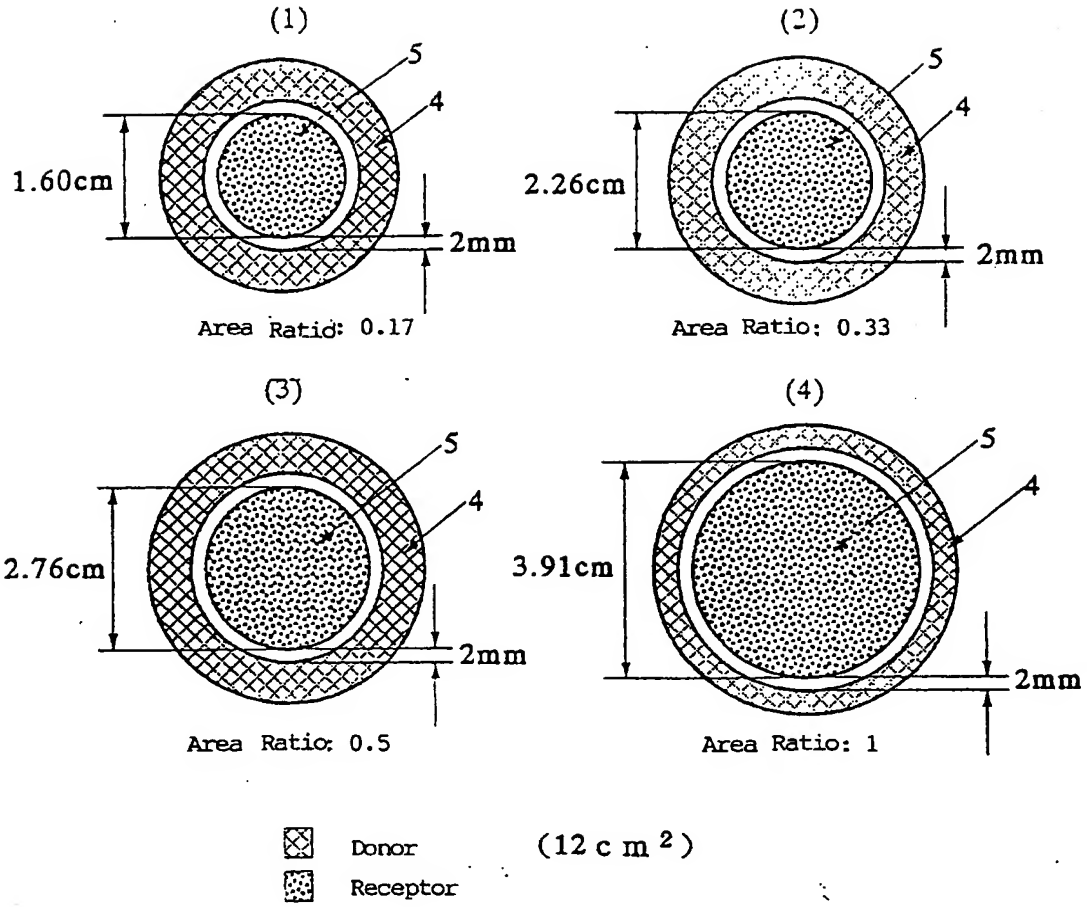

(1)
5
4
1.60cm
2mm
Area Ratio: 0.17
(2)
5
4
2.26cm
2mm
Area Ratio: 0.33
(3)
5
4
2.76cm
2mm
Area Ratio: 0.5
(4)
5
4
3.91cm
2mm
Area Ratio: 1
Donor
Receptor
(12 c m 2)

Fig. 32

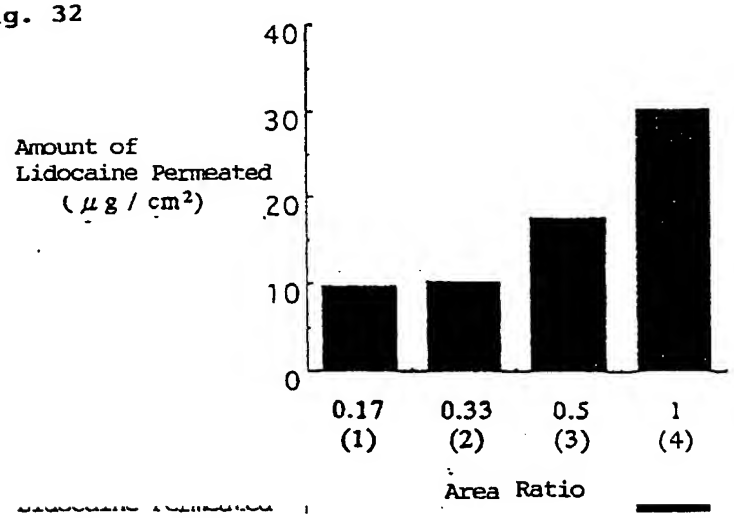

Amount of
Lidocaine Permeated
(μg / cm2)
40
30
20
10
0
0.17
(1)
0.33
(2)
0.5
(3)
1
(4)
Area Ratio

Fig. 33

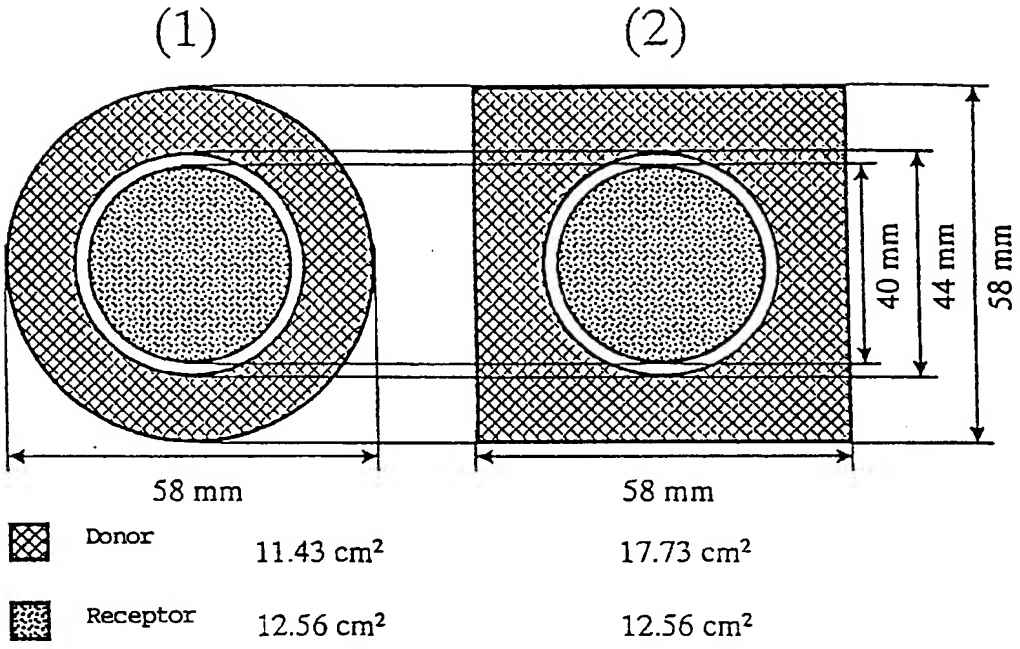

(1)
(2)
40 mm
44 mm
58 mm
58 mm
58 mm
Donor
11.43 cm²
17.73 cm²
Receptor
12.56 cm²
12.56 cm²

Fig. 34

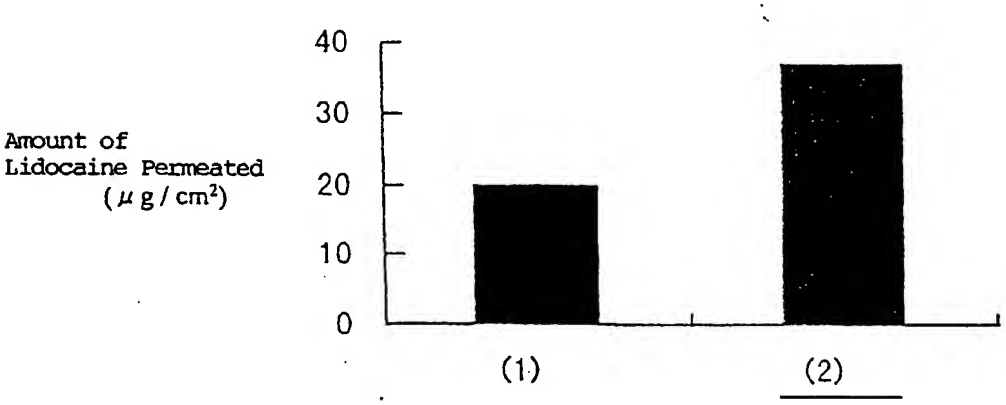
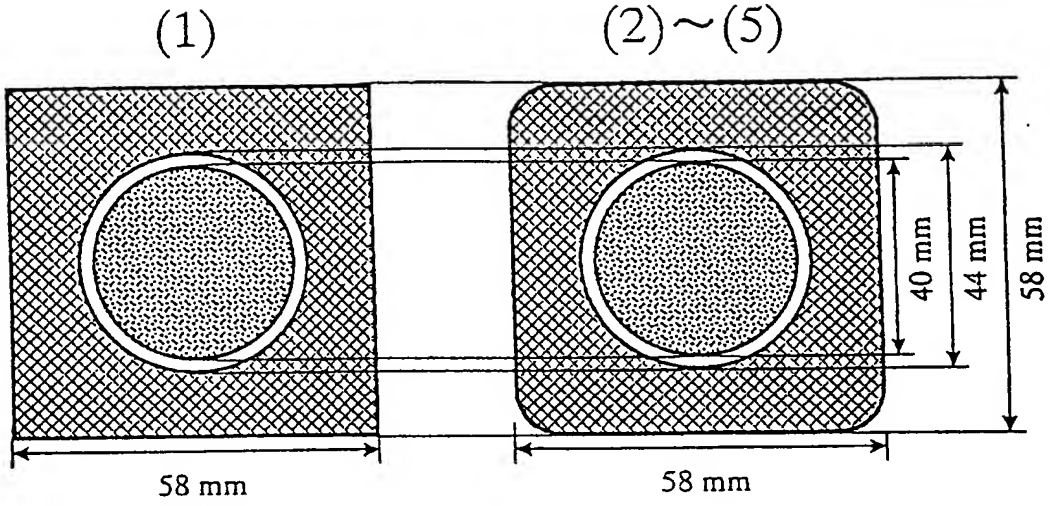
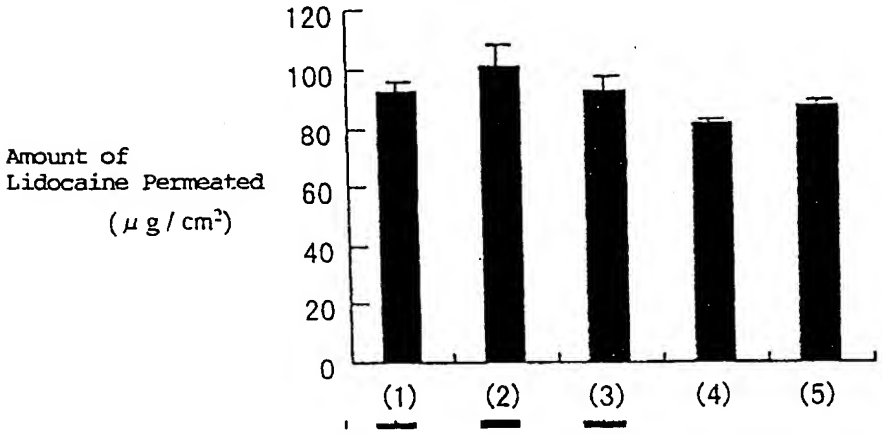

Amount of
Lidocaine Permeated
(μg/cm²)
40
30
20
10
0
(1)
(2)

Fig. 35



	(1)	(2)	(3)	(4)	(5)
Corner Radius	0.00	2.50	5.00	7.50	10.00
Donor Area	18.43	18.38	18.22	17.95	17.57
Receptor Area	12.57	←	←	←	←

Fig. 36



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP98/00440

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[6] A61N1/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl[6] A61N1/30

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1926-1998 Toroku Jitsuyo Shinan Koho 1994-1998
Kokai Jitsuyo Shinan Koho 1971-1998

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO, 9535132, A (HISAMITSU PHARM CO., LTD), December 28, 1995 (28. 12. 95), Fig. 7 & EP, 774272, A	1-11
X	WO, 9527528, A (ALZA CORP.), October 19, 1995 (19. 10. 95), Fig. 2 & US, 5503632, A & EP, 754077, A & JP, 9-511662, A	1, 4, 5, 7, 8-13

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
March 30, 1998 (30. 03. 98)	April 7, 1998 (07. 04. 98)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)

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European Patent Office
Office européen des brevets

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(21) Application number : **92630083.1**

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17.03.93 Bulletin 93/11

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(54) Transdermal drug delivery device.

(57) A transdermal drug delivery device (2) includes anode and cathode electrodes (11,12) supported on a base member (10) in spaced relation to each other to define a gap therebetween, a gel (13) containing a liquid drug to be delivered covering the gap and in contact with both of the electrodes (11,12), and a liquid permeable sheet (14) covering the gel (13) containing the liquid to be delivered.

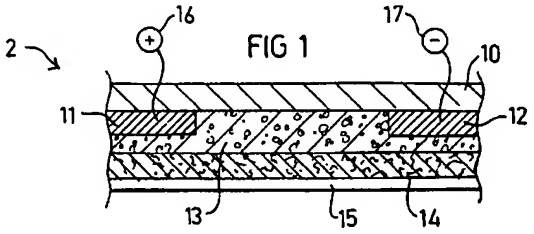


FIG 1

EP 0 532 451 A1

The present invention relates to a device for the transdermal delivery of a drug.

The transdermal delivery of a drug is frequently done by a "passive patch" or an "active patch" applied to the skin of the patient. A passive patch employs chemical potential as the driving force to deliver the drug, whereas an active patch employs an electrical potential as the driving force to deliver the drug.

Various types of active patches have been described in the literature based on iontophoresis (or electrophoresis or electroosmosis), wherein ionic (charged) molecules of the drug are delivered to the skin tissue of the patient by the passage of electric current through an electrolyte solution containing the drug. In such a technique, the drug to be delivered is contacted by only one of the electrodes. Thus, contacting the drug by the anode electrode produces positive ions which are driven into the skin at the anode, and contacting the drug with the cathode electrode produces ions with negative charges which are driven into the cathode. A review of this technique appears in the article titled "Iontophoretic Delivery of Drugs: Fundamentals, Developments and Biomedical Applications" by Ajay K. Banga and Yie W.Chien, Journal of Controlled Release, 7 (1988) 1-24.

The main drawback in the iontophoresis delivery of a drug is the danger of electric shock, skin irritation or burns, since the electrodes are in direct contact with the patient's skin. Thus, the rate of delivery of the drug to the skin is generally linearly proportional to the density of the electrical current supplied, but the power required, or heat generated, is generally proportional to the square of the electrical current supplied.

An object of the present invention is to provide a new transdermal drug delivery device for delivering a liquid drug to a patient.

According to the present invention, there is provided a transdermal drug delivery device, comprising: a base member of insulating material; an anode electrode and a cathode electrode supported on said base member in spaced relation to each other to define a gap therebetween; means for connecting the electrodes to a voltage source; and an insulating layer releasably containing a liquid drug to be delivered covering said gap and both of said electrodes. Preferably, and in accordance with the described preferred embodiments, the insulating layer is a gel releasably containing the liquid drug to be delivered, and is in contact with both of the electrodes.

It has been found that the novel device causes, e.g., the gel, to release the liquid drug at a rate having a very close linear relation to the magnitude of the current supplied, i.e., the density of the current flowing through the gel. Thus, if the current is doubled, the rate of release of the liquid drug from the gel is approximately doubled. Therefore close linear control may be provided of the drug delivery rate.

It is to be particularly noted that in the above described device, both electrodes contact the layer containing the drug to be delivered, and neither electrode contacts the patient's skin. This is to be distinguished from the iontophoresis technique for transdermal drug delivery wherein only one of the electrodes contacts the drug-containing medium and both electrodes contact the patient's skin. Accordingly, the transdermal drug delivery device constructed in accordance with the present invention provides the "control" advantage of the active patch, but not the disadvantage of the danger of electric shock, skin irritation or burns. The novel transdermal drug delivery device may therefore be called a "controlled passive patch" device.

Particularly good results have been obtained when the drug-releasing layer is a gel, and the outer face of the gel is covered by a liquid permeable sheet, preferably a porous absorbent sheet of hydrophylic material, such as porous absorbent paper.

Fig. 1 is a diagram illustrating one form of transdermal drug delivery device constructed in accordance with the present invention;

Fig. 2 illustrates another form of transdermal drug delivery device constructed in accordance with the present invention;

Fig. 3 is a plan view of the device illustrated in Fig. 2;

Figs. 4 and 5 schematically illustrate an electrode array and two types of controls for a transdermal drug delivery device constructed according to Figs. 2 and 3;

Fig. 6 illustrates the electrode array of a further form of transdermal drug delivery device constructed in accordance with the present invention; and

Fig. 7 illustrates the device of Fig. 6 as embodied in a wrist band for application to the wrist of a patient.

The transdermal drug delivery device illustrated in Fig. 1, therein designated 2, comprises a base member 10 of insulating material, such as a plastic sheet. An electrode 11 and a cathode electrode 12 are applied to one face of base member 10 in spaced relation to each other so as to define a gap between the two electrodes. A layer of gel 13, containing the liquid drug to be delivered, is applied over the two electrodes 11, 12, so as to be in direct contact with both electrodes and also to fill the gap 13 between both electrodes. The opposite face of the gel layer 13, i.e., opposite to that facing the base sheet 10, is covered by a hydrophylic liquid-permeable sheet 14, preferably a sheet of porous absorbent paper. The device is to be applied with sheet 14 in direct contact with the skin 15 of the patient to receive the drug transdermally.

It has been found that when the anode 11 and cathode 12 are connected to a source of electrical current, e.g., via their respective terminals schemat-

ically indicated at 16 and 17, the liquid drug contained within the gel layer 13 is released from the gel at a rate which depends generally linearly on the magnitude of the electrical current through the gel layer. This liquid drug is absorbed by the sheet 14 and is delivered to the patient's skin 15. Thus, by controlling the magnitude of electrical current applied to the two electrodes 11, 12, the rate of release of the drug from the gel 13 to the porous paper sheet 14, and thereby the rate of delivery of the drug to the patient's skin 15, can be controlled.

As one example, the gel could be a hydrogel, and the liquid drug to be delivered could be nitroglycerine. It was found that in such a gel-drug mixture, applying one milliamp of electric current between the two electrodes released the drug from the gel at a rate of .01 cc/min, whereas when the electric current was increased to 10 milliamps, the rate of release was correspondingly increased to about 0.10 cc/min.

In addition to nitroglycerine, other drugs may be delivered in this manner, such as a beta-blocker, analgesics, and many of the other drugs mentioned in the above-cited review by Ajay J. Banga and Yie W. Chien.

Figs. 2 and 3 illustrate a transdermal drug delivery device embodied in the form of a patch that may be adhesively applied to the patient's skin. The device, generally designated 20 in Figs. 2 and 3, comprises a body member including base sheet 21, e.g., of flexible plastic material, and a layer 22 of resilient plastic material bonded to the inner face of sheet 21. Layer 22, e.g., of sponged plastic material, embeds a microprocessor 23, a battery 24, and an electrical switch 25, for supplying power to the device. A printed circuit film 26 is bonded to the outer face of layer 22. The outer face of the printed circuit film 26 carries an array of electrically-conductive pathways, as more particularly illustrated in Fig. 4, which pathways constitute an anode electrode 27 and a cathode electrode 28.

A layer of a gel 29, containing the liquid drug to be delivered by the device, is applied to the outer surface of the printed circuit film 26 to cover, and to be in good contact with, the two electrodes 27 and 28. A sheet of a hydrophylic liquid-permeable material 30, such as porous absorbent paper, is applied to the outer face of the gel layer 29. A peelable protective film 31 covers the outer face of the liquid-permeable sheet 30 and the inner face of the base film 21, and is removably retained in place by adhesive on the underface of the base sheet.

As shown in Fig. 4, each of the two electrodes 27, 28 includes a plurality of branches electrically connected together but physically spaced from each other, with the branches of one electrode being paired with, but spaced from, the branches of the other electrode to form a plurality of gaps all of which are covered by the gel layer 29. Thus, the anode electrode 27 includes a plurality of branches 27a-27n in the form of parallel, spaced strips of conductive material; and similarly the cathode electrode 28 includes a plurality of branches 28a-28n also in the form of parallel, spaced strips alternating with the strips 27a-27n of the anode electrode. A plurality of parallel gaps are thus formed between the anode electrode sections 27a-27n, and the respective cathode electrode sections 28a-28n.

The gel layer 29 covers these parallel gaps and is in good contact with all the above branches of the anode and cathode electrodes. When battery 24 is connected by switch 25 to the two electrodes 27, 28, an electrical current, under the control of microprocessor 23, thus flows through the gel bridging the gaps between each pair of these electrode branches. As described above, the gel layer 29 releases the liquid drug contained in the layer at a rate substantially linearly to the density of the current through the gel. The released drug is absorbed by the porous paper sheet 30 in contact with the patient's skin and is thereby applied to the patient's skin at a rate corresponding to the density of the current passing through the gel layer.

Microprocessor 23 may be pre-programmed to control the magnitude (or density) of the electrical current supplied to the two electrodes 27, 28, and thereby the rate, as well as the time, of delivery of the liquid drug from the gel layer 29.

Fig. 5 illustrates a variation in the construction of the device, in that instead of including a microprocessor 23, there is included merely a presettable resistor 23' to control the magnitude of the electrical current applied to the electrodes, and thereby the rate of delivery of the drug. The construction and mode of operation of the device illustrated in Fig. 5 are otherwise the same as that described above with respect to Fig. 4.

In the device of Figs. 2-5, the electrical switch 25 may have an operator (not shown) which is exposed on the outer face of the base sheet 21, so that the electrical switch can be closed after the patch has been applied. Alternatively, the electrical switch 25 can be included in the microprocessor 23 and conveniently actuated in any suitable manner, i.e., when the protective film 31 is stripped from the adhesively-coated base sheet 21 at the time the device is applied to the patient's skin.

Fig. 6 illustrates a device which may be similar to that described above with respect to Figs. 2-5, except for the construction and disposition of the two electrodes on the printed circuit film 26. Thus, in the construction illustrated in Fig. 6, the two electrodes are arranged in a plurality of groups occupying different areas of the printed circuit film (26), and thereby of the base sheet 21. This enables the electrodes of each group to be selectively energized at different times (and also with different current magnitudes) for

purposes of dispensing the drug of the gel layer (29, Fig. 2) in the respective area at different times (and at different rates, if desired).

Thus, as shown in Fig. 6, the anode is constituted of an array, generally designated 40, constituted of a plurality of separate anode electrodes 41-48, with each anode electrode including a plurality of branches 41a-41n, 42a-42n, etc., in parallel spaced relation to each other. The cathode electrode, generally designated 50, is similarly formed of a plurality of electrodes 51-58 but, in this case, all electrically connected together. Each cathode electrode 51-58 includes a plurality of straight branches 51a-51n, 52a-52n, etc., also in parallel spaced relation to each other, but in staggered relation with respect to the branches of the anode electrode.

The anode electrode sections and cathode electrode branches thus define eight groups of anode-cathode electrodes in eight different areas of the device. All of these electrodes are covered by the gel layer (29, Fig. 2) containing the drug to be delivered. Only one of the eight groups of electrodes may be energized at any one time so as to cause only that portion of the device to deliver the drug, all under the control of the microprocessor (23, Fig. 4). The microprocessor 23 may be pre-programmed so as to energize only one of the eight groups of electrodes each predetermined time period, according to the particular drug delivery regimen.

Fig. 2 illustrates the drug delivery device applied in the form of a patch adhesively bonded to the skin of the patient. Fig. 7 illustrates a variation, wherein the drug delivery device, therein designated 60, is applied in the form of a wrist band to the wrist of a patient. Thus, the device illustrated in Fig. 7 includes a strap 62 and a buckle 64 for applying the device to the patient's wrist. The drug delivery device 60 in the Fig. 7 embodiment may otherwise be the same as described with respect to Figs. 1-6.

Claims

1. A transdermal drug delivery device, comprising:
   a base member of insulating material;
   an anode electrode and a cathode electrode supported on said base member in spaced relation to each other to define a gap therebetween;
   means for connecting said electrodes to a voltage source;
   and an insulating layer releasably containing a liquid drug to be delivered covering said gap and both of said electrodes.

2. The device according to Claim 1, further including a liquid permeable sheet covering said insulating layer releasably containing the liquid to be delivered.

3. The device according to Claim 2, wherein said liquid permeable sheet is a porous absorbent sheet of hydrophylic material.

4. The device according to any one of Claims 1-3, wherein said base member includes a backing sheet having an adhesive coating for adhesively applying the device to a patient's skin with the liquid permeable sheet in contact with the patient's skin.

5. The device according to any one of Claims 1-3, further including a wrist band for applying the device to the wrist of a patient, with the liquid-permeable sheet in contact with the patient's skin.

6. The device according to any one of Claims 1-5, wherein said base member further supports a battery having its positive-terminal connected to said anode electrode, and its negative-terminal connected to said cathode electrode for supplying current to said insulating layer via said electrodes.

7. The device according to Claim 6, wherein said base member further supports an electrical control means for controlling the current supplied to said insulating layer.

8. The device according to any one of Claims 1-7, wherein each of said electrodes includes a plurality of branches electrically connected together but physically spaced from each other, the branches of the anode electrode being paired with, but spaced from, the branches of the cathode electrode to form a plurality of gaps, all of which gaps are covered by said insulating layer releasably containing the liquid drug to be delivered.

9. The device according to Claim 8, wherein said electrode branches are in the form of parallel strips, the strips of the anode electrode branches alternating with the strips of the cathode electrode branches.

10. The device according to any one of Claims 1-9, wherein said insulating layer releasably containing a liquid drug to be delivered is a gel.

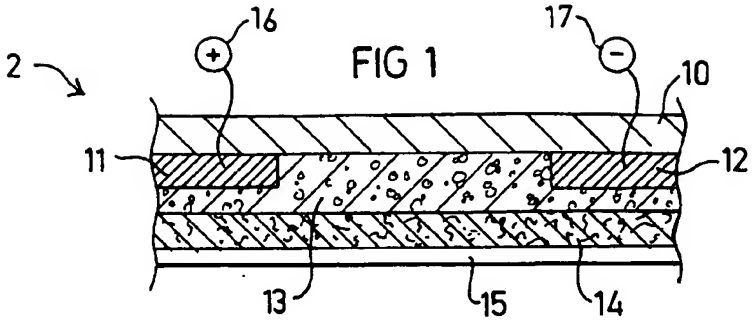


FIG 1

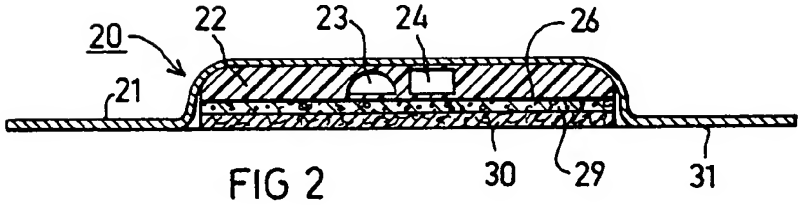
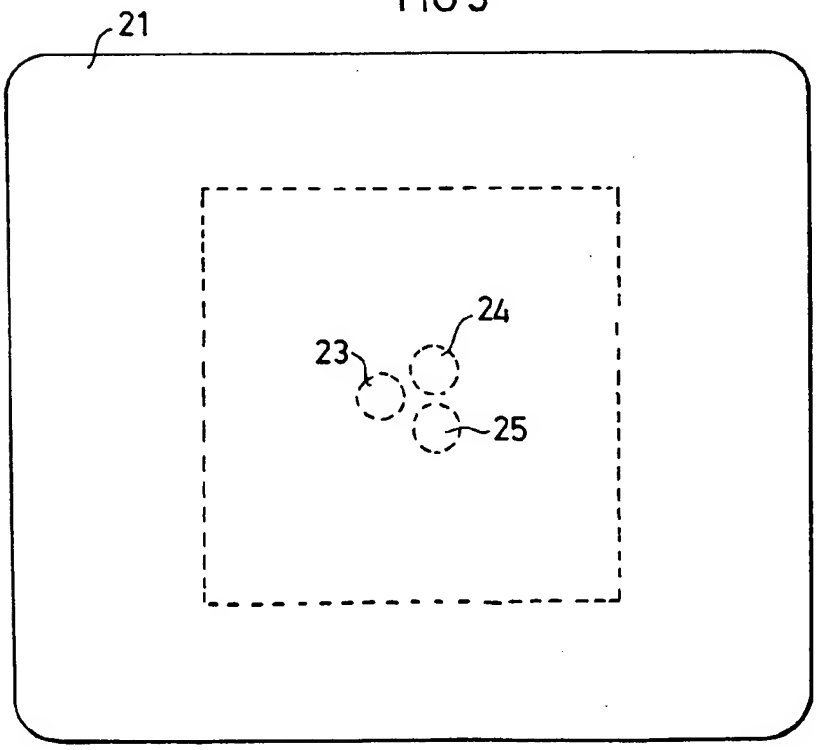


FIG 2

FIG 3



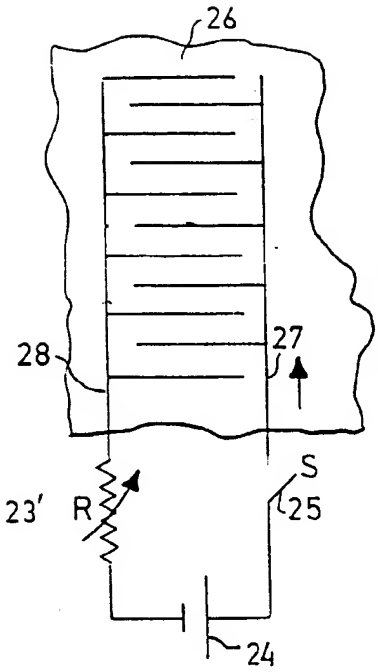


FIG 5

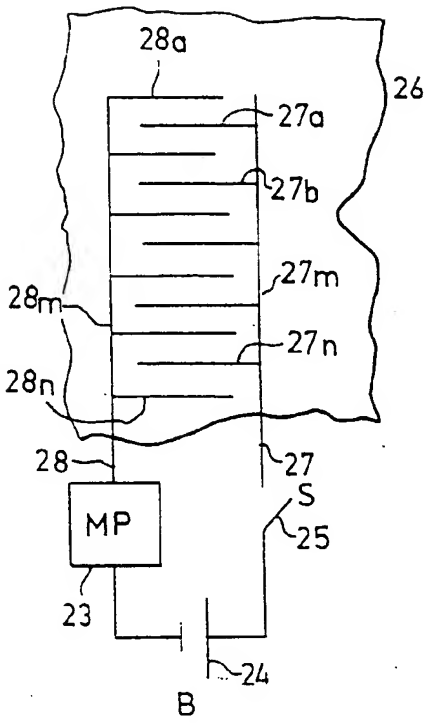


FIG 4

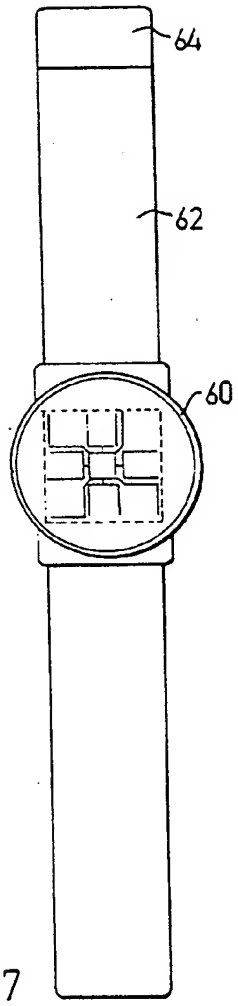


FIG 7

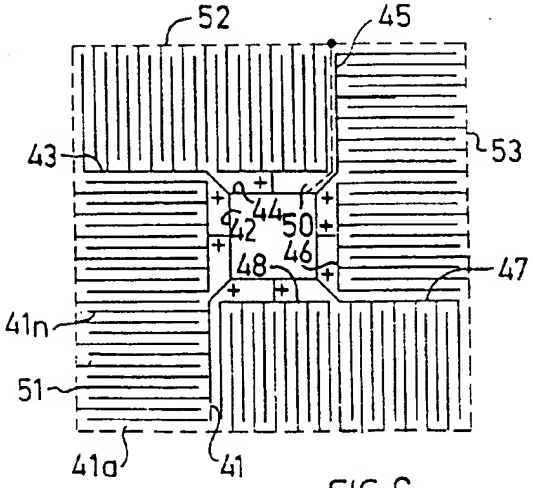


FIG 6

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Application Number EP 92630083.1

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	AT - B - 371 342 (R. TAPPER) * Fig. 1,2; page 2, lines 1-6; page 3, lines 22-47; page 3, line 53 - page 4, line 3; page 4, line 52 - page 5, line 3; page 5, lines 19-22; claim 1 *	1	A 61 N 1/30
A	EP - A - 0 417 290 (R. OKABE) * Fig. 1-4,6,7; column 1, line 48 - column 2, line 8; column 3, lines 20-34; column 4, lines 21-30; column 4, line 46 - column 5, line 38; column 7, line 10 - column 8, line 3; column 10, line 7 - column 11, line 32; claims 1-3, 6-8,11,12 *	1,4,6, 7	
A	US - A - 4 722 726 (J.E. SANDERSON et al.) * Fig. 2; column 5, lines 25-61; column 6, lines 56-61 *	1,4	TECHNICAL FIELDS SEARCHED (Int. Cl.5) A 61 N
A	US - A - 4 878 892 (D. SIBALIS et al.) * Fig. 1; column 8, lines 1-58; column 8, lines 5-32 *	1-5,10	
A	US - A - 5 042 975 (Y.W. CHIEN et al.) * Fig. 1,8,9; column 6, lines 9-28; column 7, line 65 - column 8, line 42 *	1,5-7	
A	US - A - 5 002 527	1,6,7,	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	01-12-1992	LUDWIG

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EUROPEAN SEARCH REPORT

Application Number

EP 92630083.1

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
	(CH. RELLER et al.) * Totality; especially fig. 1,2,9; column 6, lines 29-48; column 7, lines 11-20; claims 1,4 * ----	10	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
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